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M.Sc.Med. 1998

THIS THESIS HAS BEEN ACCEPTED
FOR THE AWARD OF THE DEGREE
IN THE FACULTY OF MEDICINE

THE ROLE OF SWALLOWING DYSFUNCTION IN ACUTE EXACERBATIONS OF CHRONIC AIRFLOW LIMITATION

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A thesis submitted in fulfilment

of the requirements for the degree of

Master of Science in Medicine

Faculty of Medicine **University of Sydney**

March, 1998

Dept. of Med.

PREFACE

This thesis records the results of experimental work performed between 1996 and 1997 within the Respiratory, Speech Pathology and Radiology Departments of Concord Repatriation General Hospital. All work was performed under the supervision of Dr Matthew J. Peters, Respiratory Specialist and Monika N. Kaatzke - McDonald, Speech Pathologist (Clinical Grade 5) Concord Repatriation General Hospital.

All studies were approved by the Institutional Ethics Committee of Concord Repatriation General Hospital. Informed consent was obtained from all human subjects prior to their participation.

All the work herein presented is the work of the author with the following exceptions:

1. Spirometry was performed by the respiratory scientists of the Respiratory Unit, Concord Repatriation General Hospital.

2. Ms Joanne Smith and Ms Kate Garvey, Speech Pathologists, performed the bedside examinations as the author performed the modified barium swallows which would have interfered with the objectivity of the bedside examination results.

3. Ms Monika Kaatzke - McDonald, Speech Pathologist, and Dr Tom Anderson, Radiologist, rated the modified barium swallows in addition to the author.

The author was responsible for all data collation, and preparation of graphs and illustrations.

ABSTRACT

Infective exacerbations of Chronic Airflow Limitation (CAL) are a major respiratory health issue. Diagnostic related group (DRG) 177 is the most costly respiratory DRG in NSW costing on average $47 million per year. Bronchial infection, with organisms normally found in the upper airway, is the commonest precipitant. **Hypothesis:** Swallowing dysfunction and aspiration in susceptible individuals might be the basis for recurrent bronchial infection. **Methods:** 15 patients with a history of two exacerbations within 12 months or three in two years were studied along with 15 age-matched well controls. A standard questionnaire was administered followed by clinical examination and a modified barium swallow. In order, 50% water / 50% liquid barium in two single sips, 100mls 50% water / 50% liquid barium continuous, pear piece in syrup, biscuit and sandwich were studied. Single sips, 100mls and biscuit were restudied after sufficient step exercise to generate moderate dyspnoea. **Results:** The mean age was 78 ± 1 for both groups. CAL patients reported more frequently coughing after drinking but not eating and having slowed their eating and drinking. On the modified barium swallow the CAL patients took longer to swallow single sips of liquid, 100mls of liquid and pear piece. They had difficulty chewing solids, a delayed onset on the pharyngeal phase of the swallow across solids and liquids which increased after stress. Valleculae residue was seen in some subjects and one third of patients aspirated predominately on liquids. **Conclusion:** Patients with recurrent exacerbations of CAL have evidence of swallowing dysfunction not seen in age-matched controls. Aspiration of pharyngeal contents during swallowing may be an important factor in producing recurrent exacerbations of CAL.

ACKNOWLEDGEMENTS

I would like to express my thanks to friends and colleagues for their encouragement through the course of the project.

In particular I would like to thank my two supervisors, Dr Matthew Peters and Monika Kaatzke - McDonald, whose constant support, encouragement and constructive comments were invaluable. I would also like to thank the Speech Pathology Department of Concord Hospital in particular Kate Garvey and Joanne Smith.

A special thanks to my family and friends, for their patience and support throughout this time.

Lastly, I would like to thank my husband Scott, for his love, support and understanding.

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ABBREVIATIONS OF TERMS USED IN THIS THESIS

Chronic Airflow Limitation	CAL
Forced Expiratory Volume in One Second	FEV1
Diagnostic Related Group	DRG
Modified Barium Swallow / Videofluroscopy	MBS
Shortness Of Breath	SOB

INTRODUCTION

Infective exacerbations of Chronic Airflow Limitation (CAL) are a major respiratory health issue in Australia. In NSW between 1995-1996 there were 13,370 admissions coded to the DRG 177 covering infective exacerbations of CAL. This makes it the second most common reason for hospital admission for respiratory disease. With an average cost of $3503 per admission and an overall cost of $46.8 million, the economic burden to the health system is substantial (NSW 1994-1995 NSW Dept of health).

Acute exacerbations of CAL are most commonly precipitated by bacterial bronchial infection. The organisms most frequently cultured are *Streptococcus pneumoniae*, *Branhamella catarrhalis* and *Haemophilus influenzae*. These bacterial species are typically found in the oropharynx of normal individuals. The question arises: Why are these bacteria being found in the normally sterile lungs? Aspiration of food, fluid or saliva is one possible explanation.

There is limited published data exploring the link between swallowing disorders and CAL. A spectrum of abnormalities has been described but usually in highly selected populations. Airway protection and prevention of aspiration requires close co-ordination between respiration and swallowing. CAL produces a number of "challenges" to efficient and safe swallowing. These include the effects of advanced age, rapid respiratory rate, altered patterns of respiration during swallowing and potential alterations to the sensory function of the upper airway.

It is clear that the question of whether patients with recurrent exacerbations of CAL do manifest swallowing dysfunction is an important one. It is also important to determine the most efficient, reliable method to characterise any abnormality and potential treatment methods.

THESIS AIMS AND OBJECTIVES

* To determine the prevalence of dysphagia in CAL patients with recurrent infective exacerbations.

* To compare the prevalence of dysphagia in the CAL population to the normal population of a similar age.

*To identify diagnostic indicators of dysphagia in CAL patients utilising a medical and swallowing history, and a clinical examination by a speech pathologist.

* To identify any typical dysphagic pattern on videofluroscopy in the CAL population.

NORMAL SWALLOWING

Swallowing is a complex motor act which is modified by sensory feedback according to the type of food or fluid swallowed and the method and rate of intake (1, 2, 3, 4). The swallow is commonly described as occurring in four phases: oral preparatory, oral, pharyngeal and oesophageal (5). These phases are, in reality, one continuous process. However for analytical purposes it is useful to discuss them as separate entities.

The oral preparatory phase

The bolus is made ready for swallowing during the oral preparatory phase. Textured food is masticated and mixed with saliva (6). The chewing action will vary depending on the individual's dentition and the type and quantity of material. A bolus is formed when the material has been broken down into sufficiently small particles. Solids are held on the top of the anterior tongue while semisolid or liquid boluses are generally cupped in a depression on the anterior two thirds of the tongue (7). If the bolus is large the base of the tongue may be elevated to approximate the soft palate, sealing the oropharynx and preventing premature spillage into the pharynx (6).

The oral phase

The oral phase commences when the tongue begins to move the bolus posteriorly in the mouth. The tongue sequentially squeezes the bolus backwards against the hard and soft palates in a peristaltic fashion. The force applied by the tongue is altered by the viscosity and volume of the bolus and the individual's intention. For example if the individual wants to swallow quickly greater tongue force may be used (8, 9, 10, 11). Variations in bolus formation and propulsion also occur with more textured consistencies as mastication has to be co-ordinated with bolus propulsion (12).

The oral phase is complete once the bolus passes the lower rim of the mandible. Oral transit occurs in less than one second (5) in most cases. It has been suggested that two types of liquid swallows giving slightly different transit times exist. Incisor - type swallows which are initiated with the bolus on the superior surface of the tongue and dipper - type swallows where the bolus is in anterior sublingual location. The dipper - type swallows take an additional 0.4 - 0.5 seconds. Dipper - type swallows are much less common than the incisor - type swallow so, for the purpose of this study, swallows have been assumed to be of the incisor type (13).

The pharyngeal phase

In normal individuals, the pharyngeal phase of the swallow is stimulated from a range of tactile and pressure receptor sites in the pharynx. These include the faucial pillars, pre-epiglottic sinus, glottis and the base of the epiglottis (14, 15). Once initiated a set of physiological activities are put into action that are essential for a safe and efficient swallow.

1. Elevation and retraction of the soft palate and complete closure of the nasopharynx. This prevents material from entering the nasal cavity (5, 16).

2. Initiation of pharyngeal peristalsis to pick up the bolus as it passes into the pharynx. It is then carried by the sequential peristaltic action of the pharyngeal constrictors into and through the pharynx to the cricopharyngeal sphincter at the top of the oesophagus (5, 16, 17).

3. Elevation and closure of the larynx at all three levels (epiglottis/aryepiglottic folds, false vocal cords, and true vocal cords) prevents material from entering the airway (5, 16, 17). This is associated with a reflexive inhibition of breathing (18). Swallowing apnoea commences at, or slightly before, maximum vocal cord adduction and ends as the vocal cords begin to reopen after the swallow (19). The duration of the apnoea varies with changes in the quantity of material swallowed (20, 21). Hypoventilation, causing hypoxia and hypercania can attenuate the glottic closure reflex (18). This suggests that airway protection may be compromised with the associated increase in aspiration risk during hypoventilation.

4. Relaxation of the cricopharyngeal sphincter to allow material to pass from the pharynx into the oesophagus (5, 16)

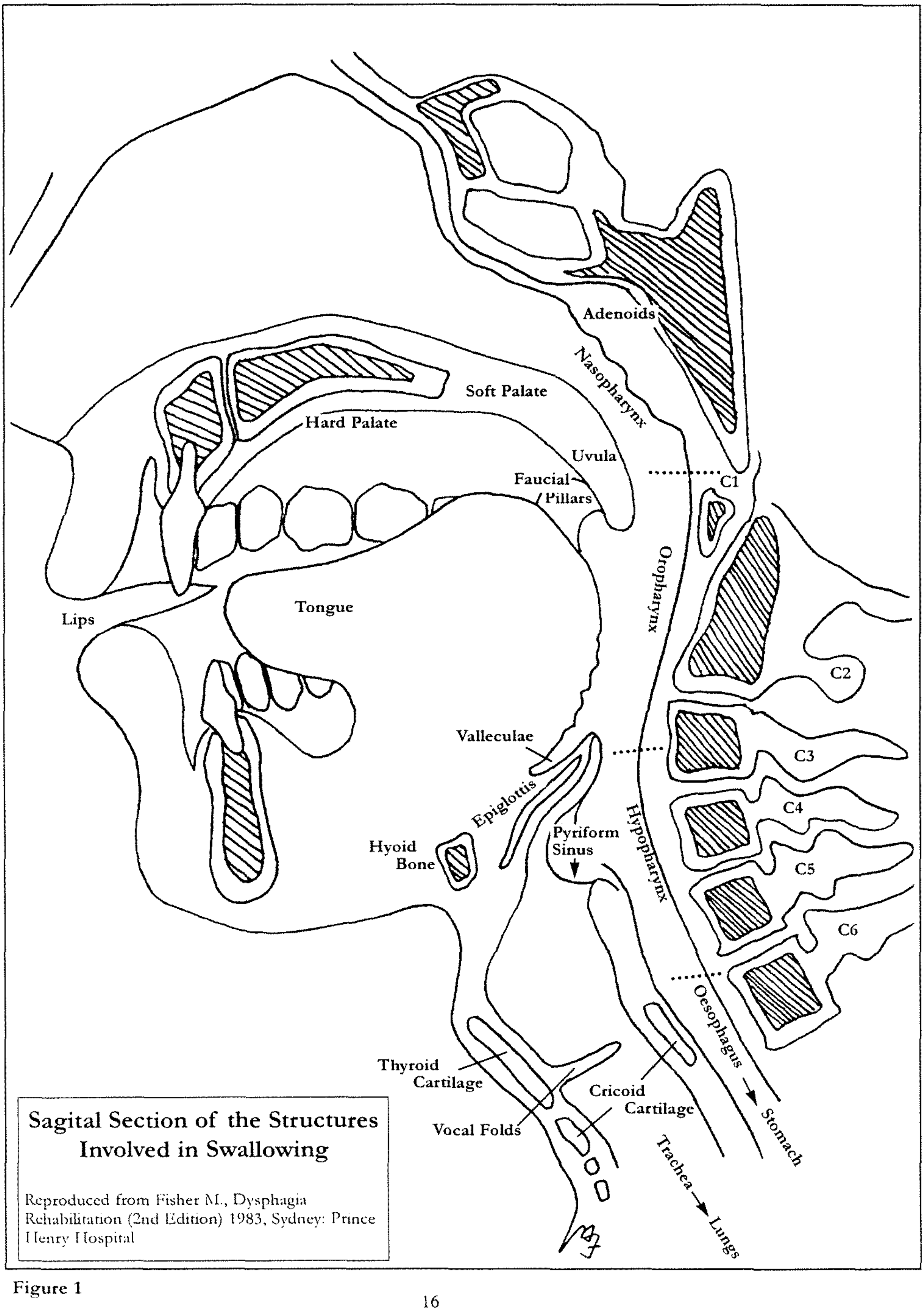
If the pharyngeal phase of the swallow is not initiated or is delayed, material propelled by the tongue into the pharynx may flow into the valleculae. Depending on the consistency of the material it may drain down the aryepiglottic folds into the pyriform sinuses and then enter the unprotected airway. Liquid or particulate matter may fall directly into the open airway (5).

The pharyngeal phase typically takes 1.2 seconds or less from the arrival of the bolus at the faucial pillars until it passes through the cricopharyngeal sphincter (13, 5, 22). The flow of the bolus is smooth and continuous. As it passes through the pharynx it divides into approximately equal portions at the epiglottis, flowing down through the pyriform sinuses. The bolus then comes together just above the oesophagus. When the pharyngeal phase is complete there should be very little, or no, food or liquid left in the pharynx (5). This is facilitated by two types of deglutitive pharyngeal contractions, pharyngeal longitudinal shortening and horizontal pharyngeal contractions. The longitudinal shortening virtually eliminates the laryngeal vestibule and pyriform sinuses preventing pooling in these areas. The horizontal contractions strip the bolus tail from the pharynx (23, 24).

Variations in bolus volume and viscosity alters the pharyngeal phase of the swallow. An increase in bolus volume results in earlier onset of superior palatal movement, anterior laryngeal movement and cricopharyngeal sphincter opening (3). The superior and anterior movements of the hyoid and thus the degree of laryngeal elevation are greater with increased volumes (1, 13, 3). Laryngeal elevation is also prolonged. Expulsion of the bolus is more vigorous with larger volumes (9). Greater bolus viscosity slows pharyngeal transit with an increased duration of the pharyngeal peristaltic waves and increased and prolonged cricopharyngeal sphincter opening (3). In some normal individuals a second clearing swallow has also been reported (25).

The Oesophageal phase

The oesophageal phase commences at the cricopharyngeal sphincter and ends at the lower oesophageal sphincter. The peristaltic wave which commenced in the pharynx continues through the oesophagus in sequential fashion. The transit times for the oesophagus vary from 8 to 20 seconds (26).



Sagital Section of the Structures Involved in Swallowing

Reproduced from Fisher M., Dysphagia Rehabilitation (2nd Edition) 1983, Sydney: Prince Henry Hospital

Figure 1

THE EFFECTS OF AGEING ON SWALLOWING

Chronic Airflow Limitation typically develops in the older individual after many years of smoking. It is against this background of general ageing that the impact of CAL on swallowing needs to be considered. Increasing age is associated with two main changes in swallowing function. Primary changes due to alterations in the anatomical and physiological composition of the body and secondary changes due to an identifiable disease process or processes. Many of these disease processes are more prevalent in the elderly including neurological, respiratory and other systemic disease (27, 28). It has been shown that 12 to 20 % of older individuals in general hospitals and 50% of those in nursing homes have dysphagia (29). These groups will have a high representation of patients with disease processes. There are no large cross-sectional studies of swallowing on the well elderly in the community.

A number changes which potentially impact on the swallowing process have been reported. These include alterations in the structure and function of muscles (30, 31, 32), decreased sensation (33, 34), a slowing in neural processing (35), and an increase in bone reabsorption (36). The amount of saliva produced decreases, it becomes more viscous and the enzyme content is reduced(36, 37).

More specifically the following changes to the oral preparatory phase and the oral phase occur. Poor mastication of the bolus is common with increased tongue movements and difficulty with bolus formation (38, 39, 36). Holding the bolus in a more posterior position prior to the initiation of the swallow has also been described (38, 40). Decreased bolus control and propulsion have been demonstrated by some authors (39). The oral preparatory and oral phases are prolonged with slower overall timing of swallowing events (41, 38). Xerostoma is common, resulting in poor lubrication of the oral cavity, limiting mixing and preliminary breakdown of food (36, 37).

During the pharyngeal phase the rate, sensitivity and efficiency of the swallow are all effected to some degree. Initiation of the swallow is generally slower with delayed initiation of the hyperlaryngeal excursion (40, 41). Swallowing sensitivity is decreased with a larger volume of food or fluid needed to stimulate a swallow (38). A reduction in swallowing efficiency is demonstrated in a number of ways. Firstly the time taken for the bolus to travel through the pharynx increases with age (41). There is an increase in the number of swallows needed to clear a single mouthful and an increase in the number of polyphasic laryngeal movements (42). Retention of the bolus in the valleculae is not uncommon (28). Elevation of the larynx and hyoid bone may be diminished resulting in reduced laryngeal closure (28, 43).

There are a number of changes in the pharyngeal phase of the swallow that may be compensating for reduced efficiency. For example the pharyngeal contractions on liquids and solids increases with age. Specifically the pressure wave amplitude and the duration of liquids in the hypopharynx increases (44, 45, 46). The prolongation of cricopharyngeal sphincter opening time reported may also be compensatory (41).

Changes in the oesophageal phase of the swallow have been described with ageing but are not within the scope of this study (47, 46, 48).

Three terms are particularly useful when describing swallowing function in the elderly. These are adaptation, compensation and decompensation (28). Adaptation is the process of modification of the normal swallow to different stimuli. For example a change in the pharyngeal peristalsis in response to an increase in the viscosity of the material being swallowed. Compensation is a change in the swallowing process to overcome a swallowing impairment. For example a reduced ability to chew food due to decreased tongue movement can be compensated for by eating soft foods. Decompensation is when a swallowing impairment is not being compensated for. For example the swallow is delayed in being initiated and fluid flows into the unprotected airway resulting in aspiration. Decompensation may occur in the same individual on some occasions and not others. For example if the person is unwell they may no longer have the energy to use the compensatory strategies they usually employ. When examining swallowing function in any population, particularly the elderly, compensatory strategies need to be identified as they may mask an underlying swallowing impairment. This impairment may only become apparent under situations of stress or illness.

Heenemann et al (36) describes ageing as being associated with a reduction in swallowing efficiency and thus reserve capacity. This increases the likelihood of environmental demands exceeding functional capacity. CAL places additional demands on the body. Therefore individuals with CAL may be unable to compensate for the changes associated with normal ageing because of their lung disease.

Further details on the aged swallow may be found in appendix A and B.

CO-ORDINATION OF RESPIRATION AND SWALLOWING

The upper airway has three distinct functions: swallowing, breathing and vocalisation. In order for each system to perform its function adequately a fine degree of co-ordination is required (20). Co-ordination of respiration and swallowing is essential for the prevention of aspiration and the maintenance of adequate ventilation (49). This co-ordination is dependent not only on intact structures and function but also on sufficient sensory feedback (50, 51, 52).

Respiration and swallowing follow a basic pattern of co-ordination. A swallow most frequently commences during the expiratory phase of respiration (53, 54, 55, 20, 52, 50, 21). This provides an airflow direction which is opposite to the direction in which the bolus is travelling (54). This improves bolus control, reducing the chance of premature entry of the bolus into the pharynx and thus unprotected larynx. During the swallow a brief period of apnoea occurs which is accompanied by laryngeal closure (53, 54, 55, 20, 52, 50, 21). The laryngeal closure provides a mechanical obstruction preventing aspiration while the apnoea prevents the bolus being drawn into the larynx during an unintentional inspiration. On completion of the swallow respiration recommences with expiration (53, 54, 55, 20, 52, 50, 21). This is thought to clear any remaining pharyngeal or laryngeal residue and thus prevent post swallow aspiration (54, 53, 51, 52).

Although the expiration, apnoea, expiration pattern is that most commonly found during swallowing, there are a number of notable variations. Increasing the bolus volume produces two distinct patterns (20). Firstly a prolongation of the swallowing apnoea occurs as the volume increases (20, 21). A prolonged apnoea has implications for those with compromised respiratory function. If the apnoea is unable to be sustained due to ventilatory requirements, respiration may recommence while food or fluid is still in the pharynx resulting in aspiration of the pharyngeal contents.

The second pattern of respiration with larger bolus volumes is for the apnoea period to remain constant but for the frequency of expiration before and after the swallow to increase (20, 19). Increasing the number of pre and post swallow expirations may be a protective mechanism to provide greater bolus control pre swallow and clear residue from the pharynx and laryngeal vestibule post swallow.

Just as a discrete bolus size influences the respiratory pattern so does continuous drinking. There are two studies that have reported the effects of continuous drinking on the respiratory pattern . The first study reported swallows during continuous drinking tended to interrupt inspiration rather than expiration (49). It has been postulated that this is a result of a physiological need to conserve energy when rapidly drinking large volumes of liquid. Inspiration is thought to aid the transport of the bolus through the oropharynx (49) due to a reduction in the pressure gradient between the hypopharynx and upper oesophageal sphincter (49, 56, 57).

The second study of continuous drinking reported a swallow commenced predominantly in the expiratory phase followed by a prolonged period of apnoea. On completion of the swallow, respiration recommenced with inspiration (21). The two different findings can be explained by different methods and rates of intake within the studies. Both patterns of respiration potentially increase the risk of aspiration. The first pattern described places the individual at increased risk of premature spillage into the pharynx and open larynx. The second pattern increases the risk of pharyngeal residue being inhaled.

Different respiratory patterns are reported in a wide range of conditions and disease processes. Ageing has been found to alter the respiratory pattern during swallowing. The proportion of swallows initiated in the inspiratory phase increases to a significant level in the elderly (63-83 years) (54). This may increase the risk of aspiration, particularly when there are coexisting swallowing problems. An increase in the swallowing apnoea in older individuals has also been reported which may compensate for increased pharyngeal transit time (50, 41).

Changes to the respiratory pattern also occur with altered levels of consciousness. In unconscious adults, swallows occur at random in the respiratory cycle (58). This may explain in part the prevalence of aspiration in individuals with reduced levels of consciousness (59). Distinct respiratory patterns are described for different neurological diseases (51).

The co-ordination of respiration and swallowing is altered in both the basal state and during acute exacerbations of CAL when compared to both young and elderly controls (54). Swallowing commences in the inspiratory phase with increased frequency, particularly during an exacerbation. Resumption of respiration is more common in the inspiratory phase. In contrast, young volunteers with induced tachypnoea increase the percentage of swallows occurring in the expiratory phase (54). One possible explanation is that young volunteers were using this as a compensatory strategy. However, individuals with CAL were unable to use this strategy because of their respiratory disease.

In normal individuals the overall pattern of breathing during eating and drinking is irregular with larger variations in tidal volume and inspiratory flow (60, 61). Increased upper airway resistance during swallowing has also been reported (61). The normal pattern of breathing is set to give adequate ventilation with the least amount of energy expended. A change to this optimal breathing pattern and greater upper airway resistance increases the work of breathing (62, 63). Normal adults are able to compensate for a decrease in breathing efficiency maintaining constant levels of ventilation (60, 61). In patients with CAL this does not appear to be the case with some patients experiencing dyspnoea during meals.

In conclusion, respiration and swallowing are integrated processes which may be influenced by changes or dysfunction in either system. This suggests that patients with CAL may be vulnerable to swallowing disorders. Whether respiration alone is responsible for the dysphagic symptoms reported is not yet clear.

CHRONIC AIRFLOW LIMITATION

CAL is characterised by limited expiratory airflow caused by loss of elastic recoil or obstruction of both the small and large conducting airways (64). The most common forms are chronic bronchitis and emphysema (65). Thurlbeck (66) advocated the term chronic airflow limitation to emphasise the fact that flow is generally limited rather than the airways being completely obstructed. There are many other synonymous terms used in the literature including chronic obstructive lung disease, obstructive airways disease and chronic obstructive pulmonary disease. For the purpose of this study the term chronic airflow limitation has been used.

Chronic bronchitis

Chronic bronchitis is defined clinically as a persistent productive cough with sputum production occurring for more than three consecutive months of the year and for not less than two successive years (67). It is characterised by airway mucosal inflammation and oedema accompanied by enlargement of the submucosal glands (68). A variety of associated lesions have been described including fibrosis, ulceration, metaplasia, increased muscularisation, airway thickening and lumenal encroachment (69, 70).The combination of mucosal oedema and the associated lesions with the increase in mucous within the lumen of the airway leads to airway obstruction and an increase in airway resistance. Airways of all sizes may be involved, however changes to the small airways are thought to be the largest contributor to physiological disturbances (68).

Emphysema

In contrast to chronic bronchitis, pulmonary emphysema is defined pathologically as permanent, abnormal enlargement of any part of the gas exchanging structures of the lungs, accompanied by destruction of respiratory tissue (69). The destruction of alveolar septa results in the merging of adjacent alveoli and enlarged terminal airspaces. This leads to a loss of the available gas exchange surface, an increase in the physiological dead space and impaired gas exchange. The destruction of the alveolar septa also causes a loss of the radial traction on small airways or a loss of the elastic recoil of the lungs. This results in the collapse of the small, unsupported airways during expiration trapping air in the distal airspaces the small airways serve. The consequence is an increase in thoracic gas volume or hyperinflation (68). In practise chronic bronchitis and emphysema are almost always associated to a greater or lesser extent because of the common etiologic agent, tobacco smoke (71, 69, 72).

Risk factors

The risk factors associated with CAL are cigarette smoking, low socio-economic class, male sex, ageing, exposure to high levels of atmospheric sulphur dioxide and particulates, bronchial hyper reactivity with or without atopy, repeated respiratory infections in infancy and childhood, and existence of another family member with the disease (71, 73).

Acute Exacerbations of CAL

Acute exacerbations are a relatively well recognised but poorly defined phenomena of CAL. The main cause is thought to be infection but the exact role of bacterial versus viral infection is not clearly understood (74). The clinical features of an acute exacerbation of CAL are cough, with increased sputum volume and purulence, wheeze and dyspnoea. If measurable, a fall in FEV1 will be seen and frank respiratory failure may ensue. As previously mentioned, this condition is a major cause of morbidity and mortality and the cost burden is high.

Bacteriology

In an acute exacerbation of CAL the sputum is almost invariably purulent. Neutrophils predominate rather than the eosinophils of asthma (75, 76). The most common organisms grown from sputum are streptococcus pneumoniae, haemophilus influenzae and moraxella catarrhalis (77, 78, 79). These bacteria colonise the normal oropharynx. The organisms may be difficult to identify if an antibiotic has been administered. The response to antibiotic therapy is rarely complete and is frequently followed by symptomatic and bacteriological relapse (80, 81, 82). It is hypothesised that this may be the result of continued reinfection due to repeated aspiration of oropharyngeal contents. Acute exacerbations of CAL may be the end result of a failure to keep oropharyngeal organisms out of the bronchial tree.

Malnutrition in CAL

A significant percentage of patients with CAL are malnourished (83). The reported incidence varies according to the patient population studied and the definition of malnourishment used. A study of stable outpatients, none of whom were using supplemental oxygen found 24% had a body weight of less than 90% of ideal (84). A similar incidence of 26% is reported in a population of patients enrolled in a pulmonary rehabilitation clinic (85). In contrast, a study of hospitalized CAL patients found 47% had a reduction of more than 10% of their usual weight (86). Other investigators have reported similar findings in this population group (87, 88). The potential impact of dysphagia on the nutritional status of this population has not been explored. Dysphagia has been reported as a probable cause of malnutrition in individuals with strokes (89).

SWALLOWING DISORDERS IN CAL

The literature exploring the link between swallowing disorders and CAL is limited. Coelho (1987) (90) studied 14 selected patients and found difficulties with both the oral and pharyngeal phases in 10 of the 14 patients. Bilateral weakness of the oral musculature and pharynx with excessive fatigue were key findings. Thirteen of the fourteen subjects had tracheostomies which may have contributed to their swallowing difficulties. Tracheostomy has been associated with subsequent swallowing dysfunction by a number of authors (91, 92, 93, 94, 95, 96, 97, 98, 99).

Stein et al (1990) (100) studied 25 non randomised patients, 21 of whom showed various degrees of cricopharyngeal dysfunction. Other aspects of the swallow were not discussed.

RESPIRATORY DEFENCE MECHANISMS

A number of variables determine the clinical outcome of an aspiration event. These include the quantity and content of the material aspirated, its Ph level, and its consistency (101). The efficiency of the individual's respiratory defence mechanisms also influences the clinical outcome. The lungs have three mechanisms to combat aspiration: The mucociliary elevator, the cough and the cellular and immune defences (71, 102).

The Mucociliary Elevator

The mucociliary blanket coats the lungs, nose, paranasal sinuses, middle ear and eustachian tubes. It consists of three layers; a gel mucous layer; a watery layer and a layer of respiratory cilia or hairs. Particles deposited in the mucociliary blanket are moved by the action of the cilia towards the mouth. This is the main mechanism for clearing particles from the airways. The rate of movement is significantly reduced in patients with CAL resulting in slower removal of aspirated material and increased risk of respiratory complications (71).

The cough reflex

A cough begins with a brief inspiration, followed by rapid glottic closure. During the period of glottic closure the expiratory muscles contract raising the intrathoracic and abdominal pressures. The glottis then opens resulting in a rapid expulsion of air removing aspirated material or mucous from the airway (103, 70, 71). A reduction in the rate and quantity of airflow due to respiratory disease may compromise the effectiveness of the cough. To cough effectively a large inhalation may be needed to get sufficient air. This can draw material from the larynx further into the respiratory tract where it is more difficult to expel.

The cough reflex is initiated in response to chemical and mechanical stimuli which activate the sensory receptors in the larynx and lower respiratory tract (104). The larynx and the extra pulmonary airway are more sensitive to mechanical stimuli and the intra-pulmonary airways are more sensitive to chemical stimuli (105). Any deterioration in laryngeal or airway sensation may negatively impact on an individual's ability to clear aspirated material. In the CAL population three factors potentially reduce airway sensation: Chronic cigarette smoking, the trauma of frequent coughing and medication.

Cellular and Immune defences

The cellular and immune defences of the lower respiratory tract are essential in the elimination of foreign bodies in the lungs (71). Any disruption to this process would increase the risk of respiratory complications as a result of aspiration.

Conclusion

When treating patients with dysphagia, the interplay between the type and quantity of material aspiration and the patients respiratory defence mechanisms needs to be considered. Unfortunately little information exists on how much is safe to aspirate and whether tolerance varies amongst different clinical groups. Clinical experience suggests that for the old and frail, the immunosupressed and the patient with CAL the consequences of aspiration are likely to be more dire and management decisions need to be made accordingly.

METHODS

SUBJECTS

15 subjects (13 males and two females) with a mean age of 78±1.4 years (range 71-88 years) and a diagnosis of an acute exacerbation of CAL were recruited prospectively on discharge from Concord Repatriation General Hospital. A log was kept of all patients discharged with an acute exacerbation of CAL, their prima facie, suitability for inclusion and reasons, if applicable, for failure to participate in the study. Investigations were performed 4-6 weeks after discharge from hospital to allow time for their medical condition to stabilise. The selection criteria were a history of smoking more than 25 pack-years and two or more exacerbations of CAL within two years of entry into the study. Spirometry was performed on the day of assessment. The mean value was 45±13.4 % predicted (range 25-75%). Subjects were excluded on the basis of a neurological disorder, previous head and/or neck surgery or a history suggestive of obstructive sleep apnoea.

15 controls (10 males and 5 females) with a mean age of 78±1.3 years (range 71-85 years) were recruited from the community. Control subjects were excluded on the basis of a history of significant respiratory illness in the last 10 years, a neurological disorder, previous head and/or neck surgery, and a history suggestive of obstructive sleep apnoea.

All of the subjects and controls were volunteers and the institutional ethics committee approved the study. Subjects signed a written consent form, which included a brief overview of the purpose of the study.

PROCEDURE

Modified Barium Swallow (MBS) / Videofluroscopy

The MBS is widely accepted as the gold standard for assessing swallowing (5). It provides a continuous radiographic image of an individual's swallow which is recorded on video. Studies are conducted with the subject in an upright position either seated or standing. A range of solid and liquid consistencies are trialed as different stimuli produce different swallowing patterns (10, 13, 3, 8, 11, 12). The effect of therapeutic manoeuvres such as head flexion and alterations in bolus volume may be investigated. The MBS looks in detail at the oral and pharyngeal phases of swallowing and the oesophageal phase is screened. Information on structural abnormalities, timing of swallowing events, flow of the bolus and aspiration are available (106). The MBS study provides the most detailed examination of swallowing physiology currently available.

For the purpose of this study, the MBS was conducted on the same day as the bedside examination with the Speech Pathologist and Radiologist present. The assessments were conducted sequentially to minimise the effect of any fluctuations in respiratory function or health status. The MBS was carried out prior to the bedside examination and questionnaire to prevent the subject being primed for the swallow and altering their usual swallowing behaviour. The subject was not told of the results of the MBS until the bedside examination and swallowing questionnaire were complete.

The X-ray equipment used was a Philips Super 80cp generator, a Philips Diagnost 66 table and a Scope 76 screening machine. Recordings were made on Super VHS tapes using a Panasonic AG-7350 video recorder. The results of the MBS analysis were recorded on a modified version of the form designed by Mendelsohn (107). (see Appendix F for a copy of the modified form). A criteria for each variable and severity rating was developed (see Appendix G for the rating criteria). Analysis of the tapes was done by the Speech Pathologist and Radiologist conducting the swallowing study and a second Speech Pathologist blinded as to whether the subject had CAL or was a normal control. Both Speech Pathologists were experienced in the interpretation of modified barium swallows. When interpretations differed, the videos were jointly reviewed until an agreement was reached. Gibson et al (108) reported rating of modified barium swallows to be reliable and accurate when done by experienced clinicians. The results of the MBS were recorded on a modified version of the form designed by Mendelsohn (107). The ratings were made according to the protocol seen in appendix G. The oral and pharyngeal phases of the swallow were timed for each consistency and volume at rest and after stress. The total time to swallow a given mouthful was also documented. The transit of the capsule was not timed because of the complication of when the sip of water was taken. A diamond stop watch was used. When the two raters times differed the average was taken.

The test protocol was developed with consideration for the particular properties of foods and liquids, the volume of food or liquid taken, the method of intake (e.g. cup vs. straw) and the subject's respiratory status. The protocols of Logemann (7) and Palmer et al (109) were used as the basis for this protocol. Changes and additions were felt to be necessary as their protocols were designed for neurological and surgically based swallowing problems. This study was designed to highlight the areas of difficulty that are potentially experienced by the CAL population. The food/fluid trials were self administered to replicate the subject's usual swallowing technique. The assessment was conducted using a lateral projection as it is the most sensitive to aspiration. The range of consistencies and projections were limited to reduce radiation exposure.

TABLE 1 - TEST PROTOCOL

The test protocol was used for both the MBS and the bedside examination.

Rest - Part one

TYPE OF CONSISTENCY	TRIAL FOOD/LIQUID	METHOD AND QUANTITY
Thin Liquid	50/50 water/liquid barium (tixibar)	2 single sips from a cup 100mls continuous
Mixed solid and liquid	Pear piece and juice Coated in barium powder	2 mouthfuls chewed
Particulate solid	Barium shortbread biscuit	1 mouthful chewed
Mixed solid	Cheese sandwich coated with barium	1 mouthful chewed
Solid (whole) in liquid	Capsule	1 taken with a sip of water

After Stress - Part two

TYPE OF CONSISTENCY	TRIAL FOOD/LIQUID	METHOD AND QUANTITY
Thin Liquid	50/50 water/liquid barium (tixibar)	2 single sips from a cup 100mls continuous
Particulate solid	Barium shortbread biscuit	1 mouthful chewed

Respiratory Stressor

A respiratory stressor was used to assess the effect of dyspnoea on each subjects' swallowing ability. It was hypothesised that during periods of increased breathlessness patients would be more likely to have swallowing difficulties and aspirate. Stepping onto a raised platform was chosen as the respiratory stressor as it could be conducted in the X-ray room. If the subject was unable to use the step due to extreme shortness of breath or physical impairment, they went for a short walk. When the patient was using continuous oxygen this was switched off for a brief period. Respiratory stress was measured in terms of shortness of breath using a variation on Borg's scale of perceived exertion (110). The scale of perceived exertion has been found to be a reliable indicator of intensity of effort (111). A subjective scale was chosen as it was quick and easy to administer. It also tapped into the subjects' perception of their level of difficulty. This was pertinent if they were compensating for shortness of breath (SOB) in their swallowing behaviour. The revised form is a eleven point scale with 0 being no shortness of breath and 10 being extreme shortness of breath. This type of measurement is routinely used by physiotherapists working in the respiratory unit and has been found to be a reliable indicator. The scale was explained to the subjects before the commencement of the MBS and they were asked to rate their perceived level of SOB. Part one of the assessment was then carried out. Part two was conducted after stress with subjects rerating SOB.

Questionnaire

For the purpose of this study a medical and swallowing questionnaire were developed (112, 113, 114, 115, 116, 117, 118, 119, 120). Information on the subjects gastroesophageal, respiratory, neurological and head and neck history were collected. Current medications were also noted. The swallowing section of the questionnaire covered current eating habits and swallowing function in a range of situations and on different foods and liquids. The questionnaire was trialed on a sample population prior to inclusion in the test protocol to eliminate ambiguous or misleading questions. The questionnaire was administered by an experienced speech pathologist to establish the subject's own perception of their swallowing ability, to look for predictive factors which might indicate a swallowing disorder and to provide a medical history in the relevant areas.

Bedside Examination

The bedside examination was included as it is routinely used by speech pathologists as a preliminary test for swallowing impairment. It is inexpensive, non invasive and requires no irradiation. It is also used to determine whether further investigations are warranted including the MBS. The bedside examination typically involves an assessment of the oromusculature and related structures. An evaluation of the relevant cranial nerves is also conducted at this time (trigeminal, facial, accessory, vagus and glossopharyngeal). A trial of a range of food and fluid consistencies is undertaken (120, 5). For the purpose of this study, the test protocol was used as previously described. Observations were made for each consistency on the individual's ability to masticate and form a bolus, time taken to initiate a swallow, elevation of the larynx and any clinical signs of aspiration or laryngeal penetration. These signs include coughing and or throat clearing, a change in breathing and changes in phonation quality. Special note was taken of the timing of events to determine at what point the swallow was breaking down. The bedside examination is able to screen for relevant cranial nerve abnormalities, detect a breakdown in many of the aspects of oropharyngeal phases of the swallowing with testing occurring in a functional situation. It is unable to detect silent aspiration and provides no visualisation of the internal workings and thus physiology of the swallow. A radiographic examination of the swallowing process is thus a necessary addition to the test battery. The bedside examination was conducted by qualified speech pathologists experienced in this type of assessment. They were blinded to whether the subject was from the CAL or normal population.

Spirometry

Spirometry measures the quantity of air exchanged during breathing and the rate of ventilation (121). Spirometry was used on CAL subjects to determine current lung function and the severity of the CAL. This method was chosen as it provides a quick, non-invasive, objective measurement of CAL (64). The CAL subjects selected for this study had already had considerable investigation for their respiratory disease during previous hospital admissions. Further investigative measures were felt to be unnecessary as the diagnosis of CAL had already been confirmed. Spirometry was used on normal subjects to confirm unimpaired lung function. A Vitalograph auto spirometer was used for this study. Calculations were made for the average forced expiratory volume in one minute as a percentage of the predicted value (FEV1).

STATISTICAL ANALYSIS

The results of the modified barium swallow analysed in a variety of ways.

Ratings for abnormal features including pharyngeal residue, laryngeal penetration and aspiration, piecemeal deglutition, bolus formation and chewing were analysed using the Wilcoxon rank sum test. The data was ordinal but the difference between each point could not be considered to be equal therefore the data was viewed as ranked. This being the case the Wilcoxon rank sum test was an appropriate statistic to use for data which comes from two samples.

The time taken for the oral and pharyngeal phases of the swallow and the total time taken to completely swallow one mouthful were compared using t tests. This type of analysis is suitable for interval type data. Comparisons were made between the CAL subjects and the normal subjects and between times within groups at rest and after stress. Comparisons at rest and after stress were done using paired t tests as the two samples were related.

The correlation coefficient was calculated for age and the spirometry result. This was to determine if there was a linear association between the timing results and these two variables.

The swallowing questionnaire and the bedside examination were analysed using chi - squared tests. This is the standard statistical analysis for two categorical variables. The sensitivity and specificity were calculated for specific questions to assess the effectiveness of the swallowing questionnaire and the bedside examination in predicting the results of the modified barium swallow.

RESULTS

ANALYSIS OF FEATURES OF THE MBS

The results of 15 normal subjects and 15 CAL subjects were analysed at rest and 15 normal subjects and 13 CAL subjects after stress. Testing was not performed after stress on two CAL subjects who had demonstrated aspiration at rest with subsequent respiratory distress. The results of the analysis are summarised in tables 2, 3 and 4 and are discussed below in terms of their main clinical features.

Chewing

There was no difference in the range and type of dentition of the CAL and normal subjects. None of the normal subjects had difficulty chewing any consistency. In contrast, 9 CAL subjects to had difficulty chewing solids. More specifically, three subjects had difficulty chewing pear piece, 6 subjects had difficulty with biscuit at rest and two others had difficulty after stress. Five subjects had difficulty chewing sandwich. The degree of difficulty experienced was mild to moderate on pear piece and biscuit and mild to severe on sandwich. The ratings of both groups were compared and CAL subjects had significantly more difficulty on biscuit at rest and after stress ($p<0.05$). The comparison between the CAL and normal subject's ratings approached significance for sandwich at rest ($0.05<p<0.1$).

Bolus Formation

The normal subjects had no difficulty with bolus formation. Three of the CAL subjects had difficulty with bolus formation, two on all consistencies and one on pear piece alone. All three subjects also had difficulty with chewing. The degree of difficulty with bolus formation ranged from mild to severe. There was no significant difference in the CAL and normal subject's ratings for degree of difficulty with bolus formation.

Piecemeal Deglutition

Piecemeal deglutition occurred on one or more consistency for 11 of the normal subjects and 11 of the CAL subjects. A comparison of the severity ratings for the CAL and normal subjects for piecemeal deglutition found the CAL subjects took significantly more swallows on single sips of liquid at rest ($p<0.05$). On single sips of liquid, 8 CAL subjects had mild to moderate piecemeal deglutition and three normal subjects had mild piecemeal deglutition.

Hypopharyngeal Residue

Hypopharyngeal residue was seen in two CAL subjects on biscuit, 1 before and after stress and a second only after stress. None of the normal subjects had hypopharyngeal residue. There was no significant difference in the overall ratings for both groups.

Posterior Pharyngeal Wall Residue

Posterior pharyngeal wall residue was seen in 1 of the CAL subjects on 100mls of liquid at rest. None of the normal subjects had posterior pharyngeal wall residue. There was no significant difference in the overall ratings for both groups.

Vallecular Residue

Vallecular residue was seen in 9 of the CAL subjects and three normal subjects. In comparison to the normal subjects, vallecular residue occurred in more of the CAL subjects on a greater number of consistencies and with greater severity. The CAL subjects rating for vallecular residue approached significance ($0.05<p<0.1$) on pear piece with syrup, biscuit at rest and after stress.

Pyriform Sinus Residue

Pyriform sinus residue was seen in three of the CAL subjects and two of the normal subjects. Of the CAL subjects one had severe residue on 100mls of liquid at rest and moderate residue on single sips and 100mls after stress, the second had moderate residue on pear piece with syrup and the third had mild residue on biscuit before and after stress. The first normal subject had moderate residue on sandwich and biscuit at rest and on biscuit after stress. The other subject had mild residue on biscuit at rest and 100mls after stress and moderate residue on 100mls at rest and single sips after stress. There was no significant difference between the ratings of the CAL and normal subjects as a whole for any consistency.

Onset of the Pharyngeal Phase

The onset of the pharyngeal phase was delayed on one or more consistencies for all the CAL and normal subjects. However the CAL subjects when compared to the normal subjects in this study had a significantly longer delay for the onset of the swallow on single sips of liquid, 100mls of liquid, pear piece with syrup and biscuit at rest ($p<0.05$). After stress there was a very significant delay in the initiation of the swallow for single sips of liquid, 100mls of liquid and biscuit ($p<0.01$).

Laryngeal Penetration / Aspiration

Laryngeal penetration occurred in 7 of the normal subjects but was only mild being transient and above the level of the cords and no aspiration occurred in 8 subjects. In contrast, Only three CAL subjects had no laryngeal penetration, three had similar mild, transient penetration and 9 had a more significant problem. Of the 9 subjects, two aspirated on single sips of liquid at rest, one silently and 1 subject had moderate laryngeal penetration. On 100mls, three other subjects silently aspirated and three had moderate laryngeal penetration. The laryngeal penetration/aspiration was significantly greater in the CAL subjects compared to the normal subjects on 100mls before stress ($p<0.05$). One CAL subject aspirated on biscuit at rest.

After stress, 1 CAL subject aspirated on single sips of and one had moderate laryngeal penetration. The subject who aspirated was unable to continue. One other subject was unable to complete the testing due to earlier aspiration. On 100mls, 1 subject had moderate laryngeal penetration. When testing 100mls after stress a number of the CAL subjects refused or were unable to drink continuously and took separate mouthfuls.

TABLE 2 - ORAL PHASE ANALYSIS

CONSISTENCY AND CONDITION		CHEWING	BOLUS FORMATION	PIECEMEAL DEGLUTITION
Single sips	CAL	NT	1.3±0.3	1.7±0.2*
Rest	Norm	NT	1.0±0.0	1.2±0.1
100mls	CAL	NT	1.3±0.3	NT
Rest	Norm	NT	1.0±0.0	NT
Pear	CAL	1.3±0.2	1.3±0.3	1.3±0.1
Rest	Norm	1.0±0.0	1.0±0.0	1.0±0.0
Biscuit	CAL	1.6±0.2*	1.3±0.2	1.5±0.2
Rest	Norm	1.0±0.0	1.0±0.0	1.5±0.2
Sandwich	CAL	1.7±0.3#	1.3±0.2	1.5±0.2
Rest	Norm	1.0±0.0	1.0±0.0	1.8±0.2
Single sips	CAL	NT	1.2±0.2	1.5±0.2
Stress	Norm	NT	1.0±0.0	1.2±0.2
100mls	CAL	NT	1.2±0.2	NT
Stress	Norm	NT	1.0±0.0	NT
Biscuit	CAL	1.7±0.3*	1.2±0.2	1.3±0.2
Stress	Norm	1.0±0.0	1.0±0.0	1.7±0.2

*** Significance at 0.01 level ($p < 0.01$) *Significance at 0.05 level ($p < 0.05$) #Approaching significance ($0.05 < p < 0.1$) NT = Not tested*

Average scores and comparison (Wilcoxon rank sum test) for chewing, bolus formation and piecemeal deglutition for CAL versus normal subjects. Scores ranged form 1 (normal) to 4 (severe abnormality). CAL subjects had difficulty chewing solids and demonstrated piecemeal deglutition on liquid. Normal subjects had no difficulty with chewing, bolus formation or piecemeal deglutition.

TABLE 3 - PHARYNGEAL RESIDUE ANALYSIS

CONSISTENCY AND CONDITION		HYPO PHARYN-GEAL	POST PHARYN-GEAL	VALLECULAR	PYRIFORM SINUS
Single sips Rest	CAL	1.0±0.0	1.0±0.0	1.3±0.2	1.0±0.0
	Norm	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
100mls Rest	CAL	1.0±0.0	1.3±0.3	1.6±0.3	1.2±0.2
	Norm	1.0±0.0	1.0±0.0	1.1±0.1	1.1±0.1
Pear Rest	CAL	1.0±0.0	1.0±0.0	1.6±0.2#	1.1±0.1
	Norm	1.0±0.0	1.0±0.0	1.0±0.0	1.0±0.0
Biscuit Rest	CAL	1.3±0.3	1.0±0.0	1.9±0.3#	1.1±0.1
	Norm	1.0±0.0	1.0±0.0	1.1±0.1	1.2±0.2
Sandwich Rest	CAL	1.0±0.0	1.0±0.0	1.6±0.3	1.0±0.0
	Norm	1.0±0.0	1.0±0.0	1.0±0.0	1.1±0.1
Single sips Stress	CAL	1.0±0.0	1.0±0.0	1.4±0.2	1.1±0.2
	Norm	1.0±0.0	1.0±0.0	1.1±0.1	1.1±0.1
100mls Stress	CAL	1.0±0.0	1.0±0.0	1.4±0.2	1.2±0.2
	Norm	1.0±0.0	1.0±0.0	1.1±0.1	1.1±0.1
Biscuit Stress	CAL	1.0±0.0	1.0±0.0	1.5±0.3#	1.1±0.1
	Norm	1.0±0.0	1.0±0.0	1.0±0.0	1.1±0.1

***(p< 0.01) *(p< 0.05) #(0.05<p<0.1)*

Average scores and comparisons (Wilcoxon rank sum test) of hypopharyngeal, posterior pharyngeal, vallecular and pyriform sinus residue for CAL versus normal subjects. Scores ranged form 1 (normal) to 4 (severe abnormality). CAL subjects experienced vallecular residue on a range of consistencies.

TABLE 4 - ONSET OF PHARYNGEAL PHASE, LARYNGEAL PENETRATION / ASPIRATION

CONSISTENCY AND CONDITION		ONSET OF THE PHARYNGEAL PHASE	LARYNGEAL PENETRATION / ASPIRATION
Single sips	CAL	2.9±0.3*	1.8±0.4
Rest	Norm	1.9±0.3	1.1±0.1
100mls	CAL	3.3±0.3*	2.7±0.5*
Rest	Norm	2.3±0.3	1.4±0.1
Pear	CAL	2.8±0.2#	1.0±0.0
Rest	Norm	2.3±0.2	1.0±0.0
Biscuit	CAL	2.6±0.2*	1.3±0.3
Rest	Norm	1.9±0.2	1.0±0.0
Sandwich	CAL	2.5±0.2	1.0±0.0
Rest	Norm	2.0±0.3	1.0±0.0
Single sips	CAL	3.0±0.3**	1.6±0.3
Stress	Norm	1.7±0.3	1.1±0.1
100mls	CAL	3.3±0.3**	1.7±0.2
Stress	Norm	2.0±0.3	1.4±0.1
Biscuit	CAL	2.6±0.3**	1.0±0.0
Stress	Norm	1.6±0.2	1.0±0.0

*** Significance at 0.01 level (p< 0.01) *Significance at 0.05 level (p< 0.05) #Approaching significance (0.05<p<0.1)*

Average scores and comparisons (Wilcoxon rank sum test) of onset of pharyngeal phase and laryngeal penetration / aspiration for CAL versus normal subjects. Scores ranged form 1 (normal) to 4 (severe abnormality) for onset of the pharyngeal phase and 1(mild, transient laryngeal penetration) to 6 (silent aspiration) for laryngeal penetration / aspiration. The initiation of the swallow was more delayed in CAL subjects and laryngeal penetration was more severe in the CAL subjects. The CAL subjects aspirated on liquids.

PHOTOS OF THE MBS

Figure 2. Difficulty chewing (pear piece)

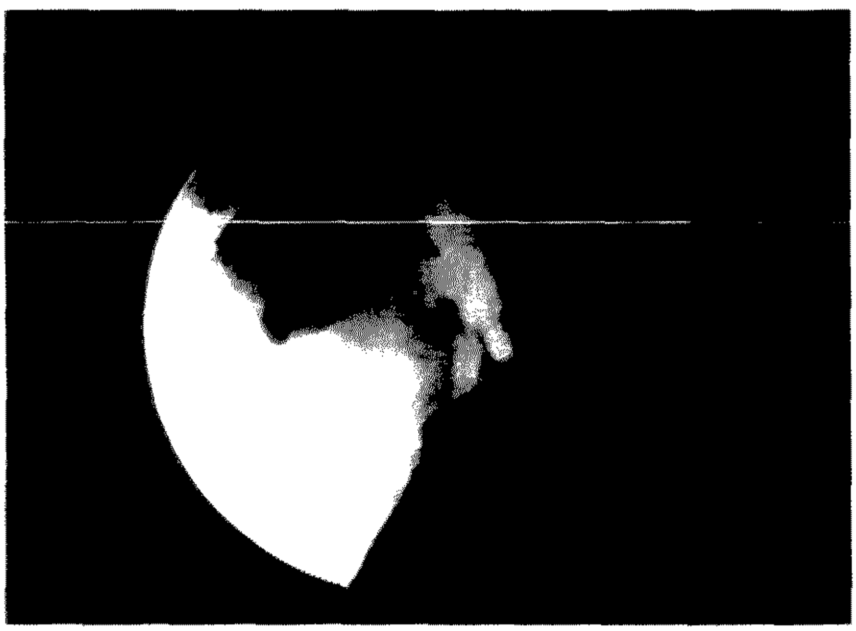


Figure 3. Delayed onset of the pharyngeal phase

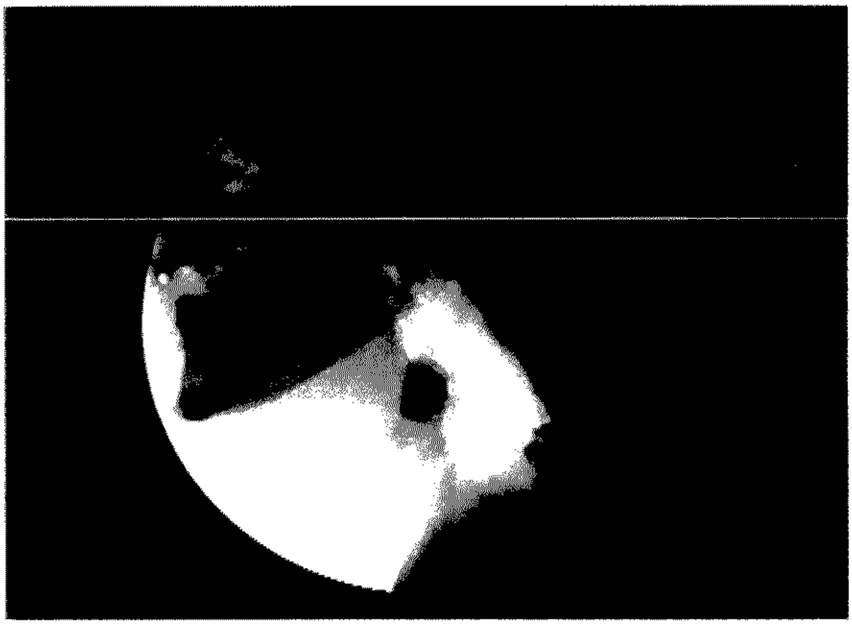


Figure 4. Vallecular and pyriform sinus residue

Figure 5. Aspiration of liquid

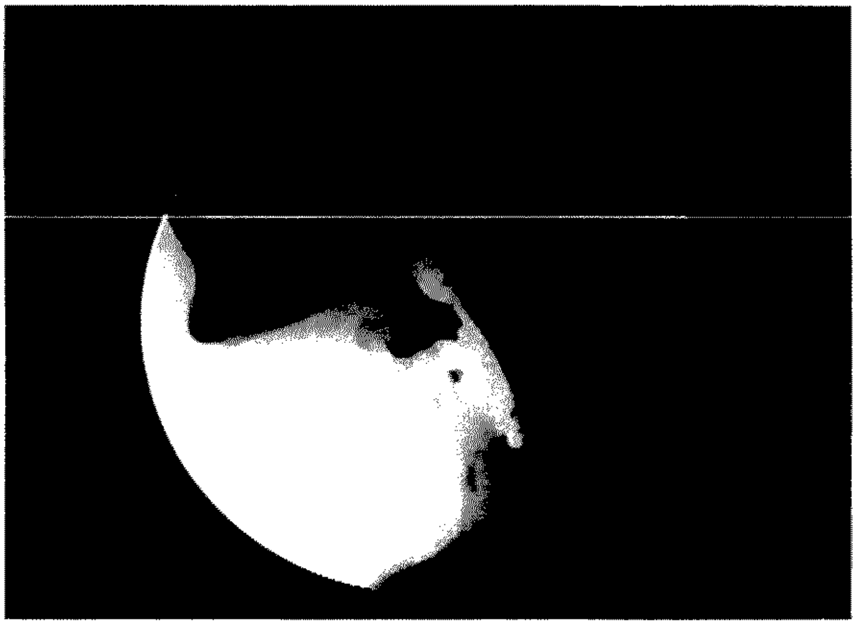


Figure 6. Aspiration of biscuit

GRAPHS OF THE MBS

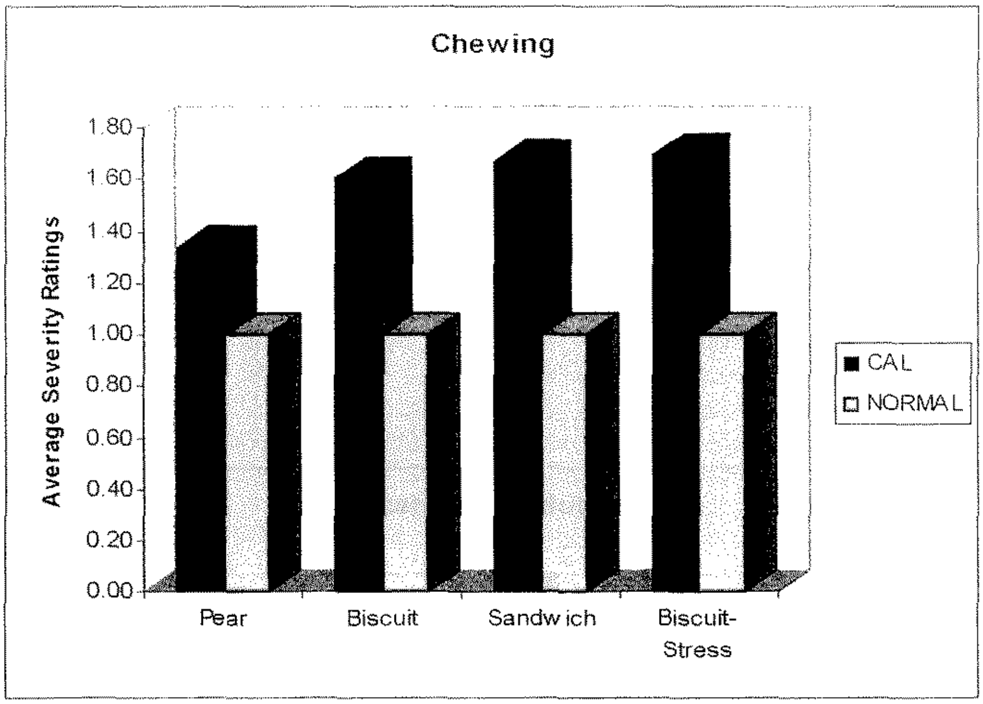


Figure 6. Graph of CAL vs normal average MBS severity ratings for chewing

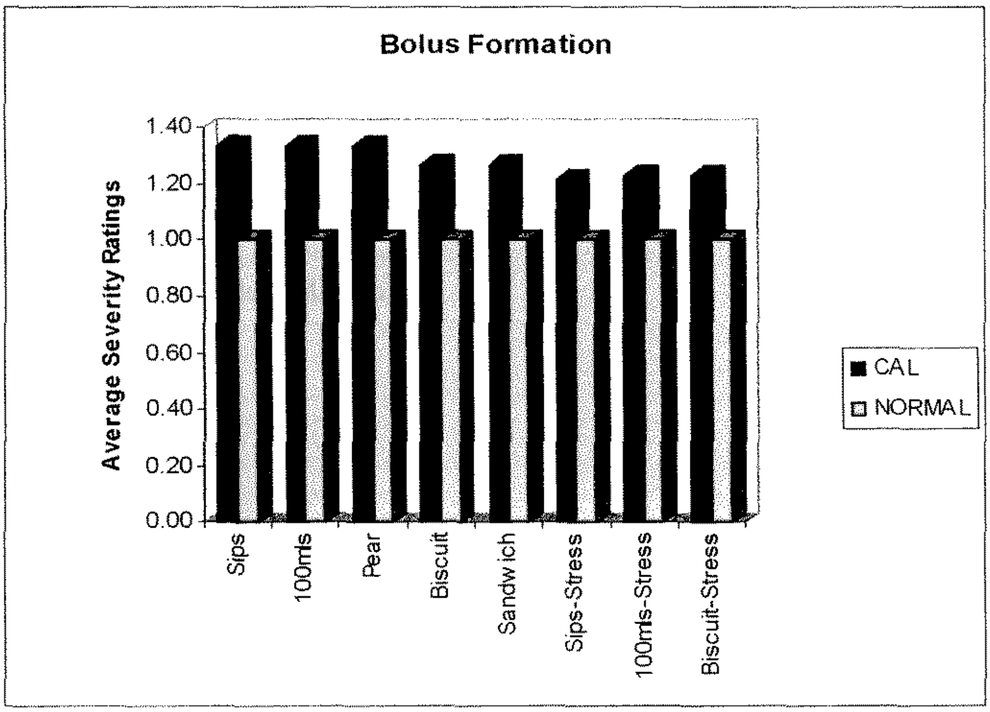


Figure 7. Graph of CAL vs normal average MBS severity ratings for bolus formation

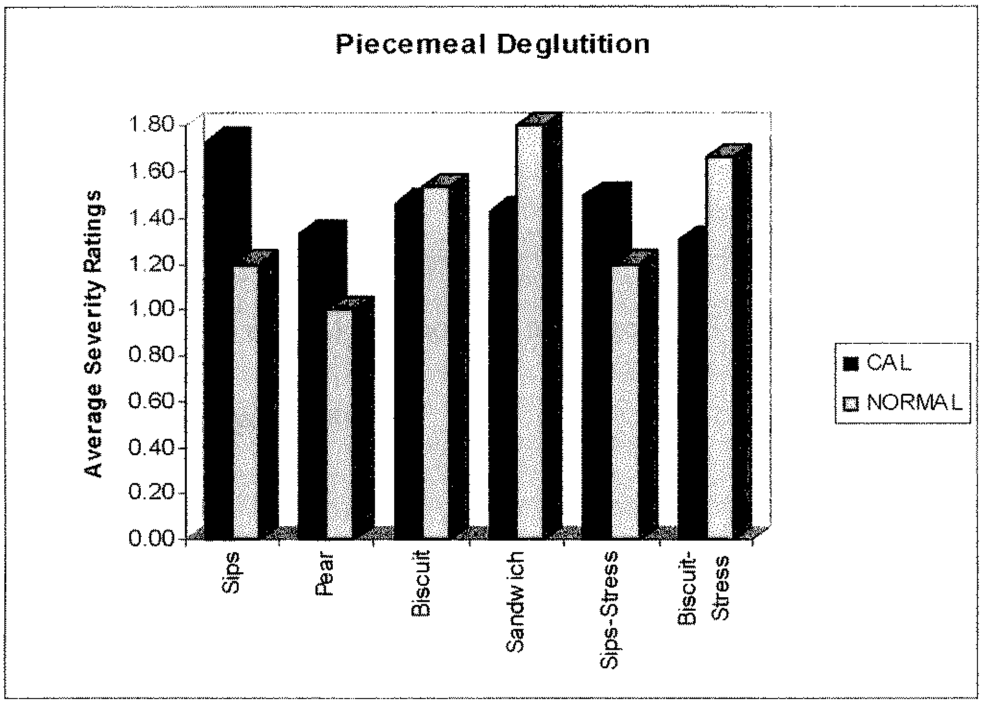


Figure 8. Graph of CAL vs normal average MBS severity ratings for piecemeal deglutition

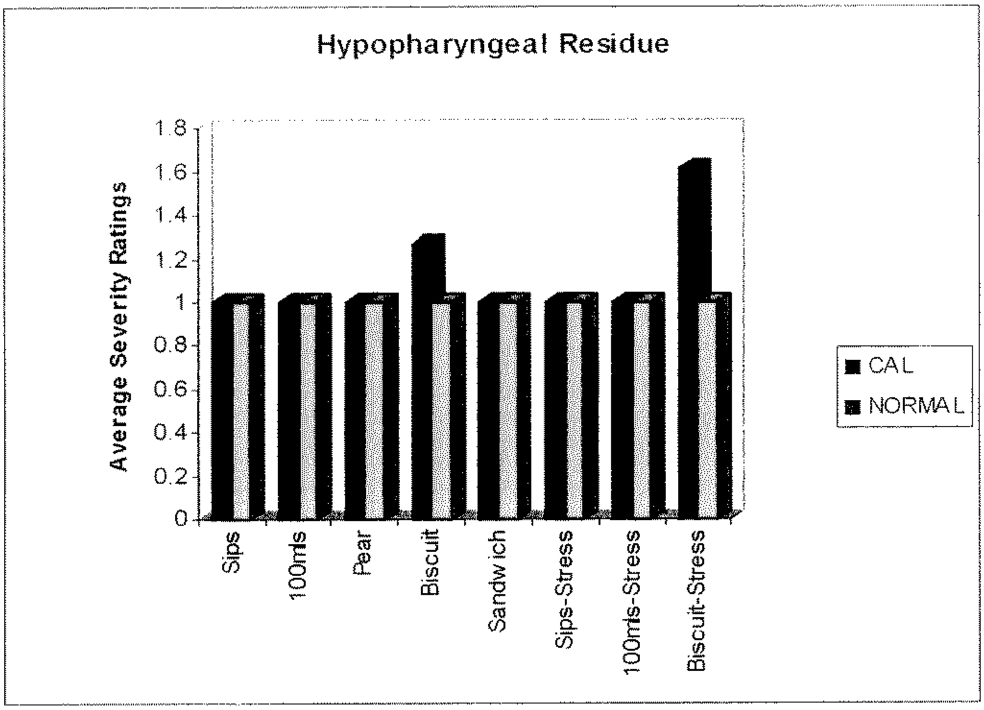


Figure 9. Graph of CAL vs normal average MBS severity ratings for hypopharyngeal residue

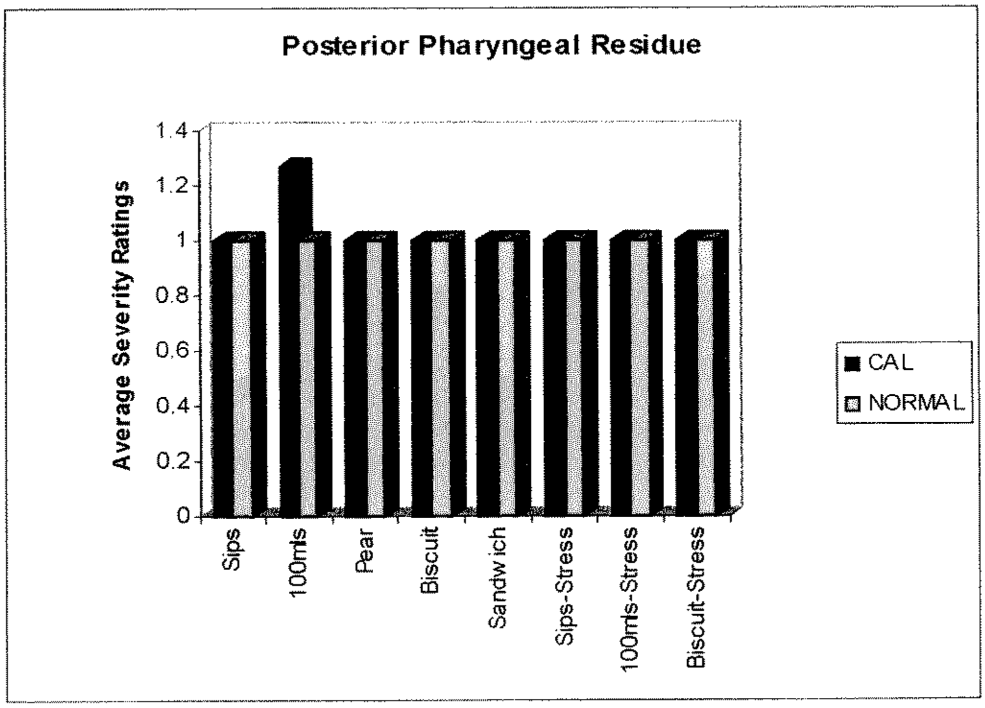


Figure 10. Graph of CAL vs normal average MBS severity ratings for posterior pharyngeal wall residue

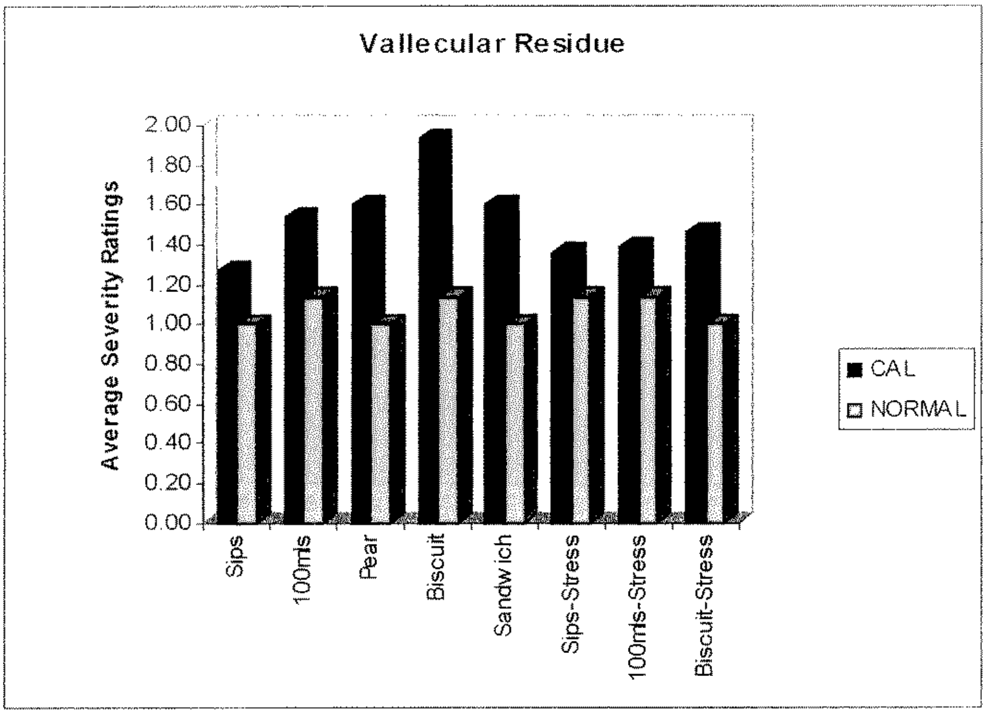


Figure 11. Graph of CAL vs normal average MBS severity ratings for vallecular residue

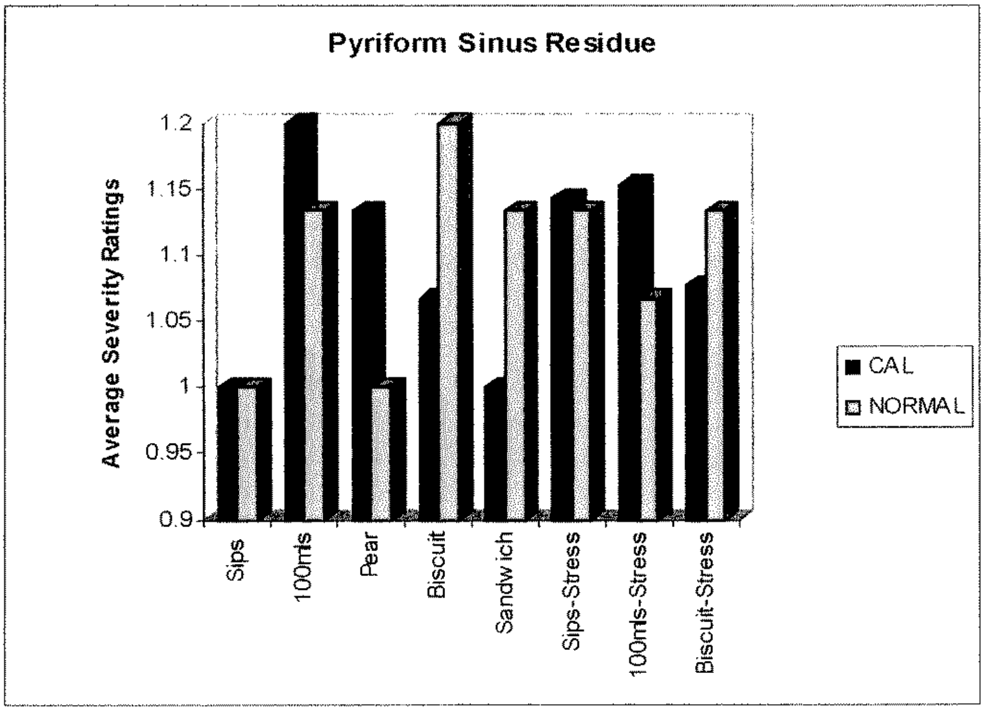


Figure 12. Graph of CAL vs normal average MBS severity ratings for pyriform sinus residue

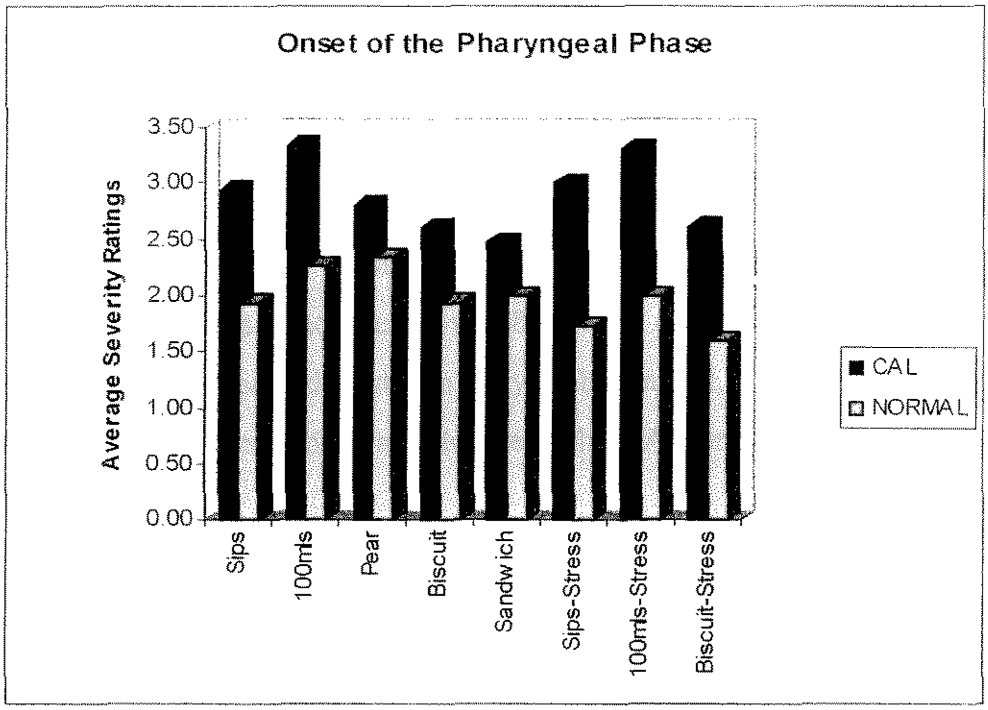


Figure 13. Graph of CAL vs normal average MBS severity ratings for onset of the pharyngeal phase

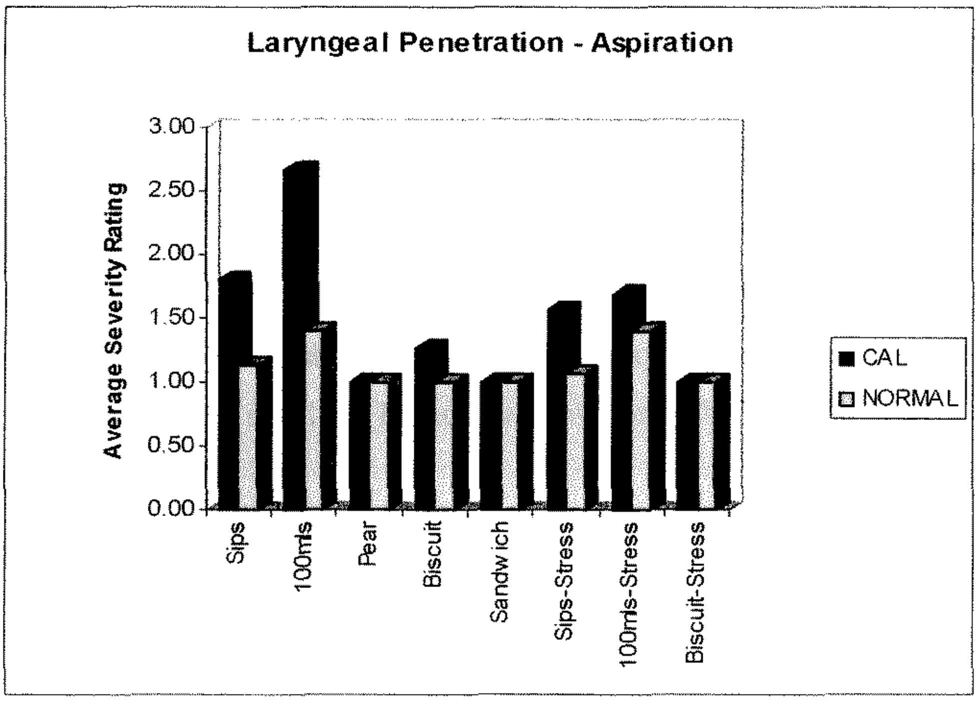


Figure 14. Graph of CAL vs normal average MBS severity ratings for laryngeal penetration / aspiration

COMPARISONS OF AGE AND FEATURES OF THE MBS

There was no relationship between chewing and age for the CAL and normal subjects. Three CAL subjects had difficulty with bolus formation and were over 80 years old. The severity of the difficulty with bolus formation was not age related and the 4 other subjects who were over 80 years old had no problems with bolus formation. Piecemeal deglutition, hypopharyngeal, posterior pharyngeal and vallecular residue were not related to age in the CAL or normal subjects.

In the CAL and normal subjects pyriform sinus residue was not related to age. The two normal subjects who had pyriform sinus residue were over 80. However, four other normal subjects who were over 80 experienced no pyriform sinus residue. The onset of the pharyngeal phase was not directly related to age. Aspiration on the modified barium swallow occurred in five of the seven subjects over 80 years old. No aspiration was demonstrated on the modified barium swallow for the 8 subjects under 80 years old. There appears to be some relationship between aspiration and age with 71% of those over 80 aspirating and 0% of those under 80. Aspiration is more likely if you are over 80 years old.

COMPARISON OF SPIROMETRY RESULTS AND FEATURES OF THE MBS

There was no relationship between the severity of the spirometry result and any of the features of the modified barium swallow for both CAL and normal subjects.

TIMING

This study found that subjects with CAL tended to swallow more slowly than normal subjects of a similar age. The averages and standard errors of the means with significant results are summarised in table 5. Not all CAL subjects were able to complete the testing after stress because of previous aspiration. The lack of significant difference between the times for the CAL and normal subjects after stress is possibly due to the loss of these more severe subjects. A small number of the other results are missing where the beginning and end of the swallow were not able to be clearly seen on tape.

Single Sips of 50% water / 50% liquid barium

At rest, 30 normal swallows were timed, two for each of the normal subjects. Twenty nine CAL swallows were timed, two for 14 of the subjects and one for one of the subjects. The CAL subjects total swallow time was significantly slower than the total swallow time for the normal subjects for the combined first and second sips of 50% water/50% liquid barium at rest. The average time for the normal subjects was 2.8± 0.3 seconds compared with 4.2± 0.6 seconds for the CAL subjects ($p < 0.05$). There was no significant difference between the oral transit times of the CAL and normal subjects. The pharyngeal transit time approached significance with the average time for the normal subjects 0.22±0.01 seconds compared with 0.27±0.02 seconds for the CAL subjects ($0.05 < p < 0.07$).

After stress, 30 normal swallows were timed, two for each of the normal subjects. Twenty three CAL swallows were timed, two for 9 subjects, 1 for 5 subjects and 0 for 1 subject. The total swallow time approached significance with the average total time for the normal subjects 2.7± 0.3 seconds compared with 3.7± 0.5 seconds for the CAL subjects ($0.05 < p < 0.07$). The lack of a significant result is possibly due to the loss of the more severe subjects due to previous aspiration. The pharyngeal transit time post stress was significantly longer in the CAL subjects with the average time for the normal subjects 0.21± 0.01 seconds compared with 0.30± 0.04 seconds for CAL subjects ($p < 0.05$). The oral transit times were not significantly different for the CAL and normal subjects.

100mls 50% water / 50% liquid barium continuous

At rest, 15 normal swallows and 14 CAL swallows were timed. The CAL subjects total swallow time was significantly slower than the total swallow time of the normal subjects. The total time for the normal subjects was 14.8± 0.9 seconds compared with 31.7± 7.6 seconds for the CAL subjects ($p < 0.05$). Individual times for the oral and pharyngeal phases were not measured because the continuous drinking did not allow these to be clearly separated.

After stress, 15 normal swallows and 13 CAL swallows were timed. The difference between the total swallow times for the CAL subjects and the normal subjects approached significance. The total swallow time for the normal subjects was 13.8± 1.3 seconds compared with 25.2± 6.5 seconds for the CAL subjects ($0.05 < p < 0.07$). The lack of a significant result again probably reflects the drop out of the more severe subjects due to previous aspiration.

Pear piece with syrup

At rest for the oral and pharyngeal phases, 28 normal swallows were timed, two for 13 subjects and one for two subjects. Twenty nine CAL swallows were timed two for 14 subjects and 1 for 1 subject. Twenty seven normal swallows were analysed for the total swallow time, two for 13 subjects, 1 for 1 subject and 0 for 1 subject. Twenty eight CAL swallows were timed for the total swallow time, two for 13 subjects and 1 for two subjects. The total swallow time for the average of the first and second mouthfuls of the pear piece at rest was significantly slower in the CAL subjects. The average total swallow time for the normal subjects was 10.5± 0.9 seconds compared with 16.2± 2.6 seconds for the CAL subjects ($p < 0.05$). The pharyngeal transit time was also significantly slower in the CAL subjects. The average pharyngeal transit time for the normal subjects was 0.22± 0.02 seconds compared with 0.34± 0.04 seconds for the CAL subjects ($p < 0.05$). There was no significant difference between the CAL and normal subjects for oral transit times. This consistency was not tested after stress.

Biscuit

At rest, 14 normal swallows and 15 CAL swallows were timed for the oral and pharyngeal phases and 14 normal swallows and 14 CAL swallows were timed for the total swallow time. The oral transit time for the biscuit at rest was significantly slower in the CAL subjects. The oral transit time for the normal subjects was 19.1± 2.5 seconds compared with 30.1± 4.8 seconds for the CAL subjects ($p < 0.05$). The pharyngeal transit time and the total swallow time were not significantly different for the CAL and normal subjects.

After stress, 15 normal swallows and 12 CAL swallows were timed for the oral and pharyngeal phases and 13 normal swallows and 12 CAL swallows were timed for the total swallow time. The difference between the CAL and normal subjects approached significance for the oral transit time with the CAL subjects swallowing slower than the normal subjects. The oral transit time for the normal subjects was 20.6± 2.3 seconds compared with 31.8± 6.0 seconds for the CAL subjects ($0.05 < p < 0.06$). The lack of a significant result probably reflects a loss of subjects due to previous aspiration and respiratory distress. The pharyngeal transit time and the total time were not significantly different for the CAL and normal subjects.

Sandwich

At rest, 15 normal swallows and 13 CAL swallows were timed. The oral and pharyngeal transit times and the total time for the sandwich at rest were not significantly different for the CAL and normal subjects. This consistency was not tested after stress.

TABLE 5 - AVERAGE TIMES FOR CAL AND NORMAL SUBJECTS

CONSISTENCY AND CONDITION		ORAL TIME	PHARYNGEAL TIME	TOTAL TIME
Single sips Rest	CAL	1.7±0.2	0.27±0.02#	4.2±0.6*
	Norm	1.5±0.2	0.22±0.01	2.7±0.1
100mls Rest	CAL	NT	NT	31.7±7.6*
	Norm	NT	NT	14.8±0.9
Pear Rest	CAL	7.3±0.6	0.34±0.04*	16.2±2.6*
	Norm	7.2±0.6	0.22±0.02	10.5±0.9
Biscuit Rest	CAL	30.1±4.8*	0.31±0.05	42.1±6.7
	Norm	19.1±2.1	0.31±0.05	31.0±3.8
Sandwich Rest	CAL	21.3±3.7	0.34±0.07	37.8±10.8
	Norm	17.4±1.7	0.25±0.02	32.4±2.8
Single sips Stress	CAL	1.4±0.2	0.30±0.04*	3.7±0.5#
	Norm	1.5±0.2	0.21±0.01	2.7±0.1
100mls Stress	CAL	NT	NT	25.2±6.5#
	Norm	NT	NT	13.8±1.3
Biscuit Stress	CAL	31.8±6.0#	0.27±0.04	45.4±6.1
	Norm	20.6±2.3	0.23±0.01	36.6±4.5

**Significance at 0.05 level ($p<0.05$) #Approaching significance ($0.05<p<0.1$)*

NT = Not tested

Average times for the CAL and normal subjects for the oral and pharyngeal stages of the swallow and the total swallow time with single sips, 100mls, pear piece, biscuit and sandwich at rest and single sips, 100mls and biscuit after stress. Comparisons (t test) were made for the timing of the oral, pharyngeal and total time for the CAL and normal subjects. In general, the CAL subjects swallowed more slowly than the normal subjects.

PAIRED TIMING ANALYSIS

Comparisons were made between the times recorded at rest and after stress for the oral and pharyngeal phases and the total swallow time for both the normal and CAL subjects. The results for both groups were not significant on any of the parameters for the single sips, 100mls continuous or the biscuit. Comparisons of the timing of single sips for CAL subjects approached significance for the oral phase with times becoming shorter after stress. The average time at rest was 1.7±0.2 seconds compared with 1.4±0.2 seconds after stress ($0.05<p<0.07$). Comparisons of the timing of the oral phase for CAL subjects for biscuit also approached significance with the time becoming longer after stress. The average time at rest for the oral phase was 30.1±4.8 seconds compared with 31.8±6.0 seconds after stress ($0.05<p<0.08$). The general trend for both CAL and normal subjects was for liquids to be swallowed faster after stress and for solids to be swallowed slower.

TABLE 6 - REST VS PAIRED TIMING ANALYSIS

CONSISTENCY AND CONDITION		ORAL TIME	PHARYNGEAL TIME	TOTAL TIME
Single sips CAL	Rest	1.7±0.2	0.27±0.02	4.2±0.6
	Stress	1.4±0.2#	0.30±0.04	3.7±0.5
Single sips Norm	Rest	1.5±0.2	0.22±0.01	2.7±0.1
	Stress	1.5±0.2	0.21±0.01	2.7±0.1
100mls CAL	Rest	NT	NT	31.7±7.6
	Stress	NT	NT	25.2±6.5
100mls Norm	Rest	NT	NT	14.8±0.9
	Stress	NT	NT	13.8±1.3
Biscuit CAL	Rest	30.1±4.8	0.31±0.05	42.1±6.7
	Stress	31.8±6.0#	0.27±0.04	45.4±6.1
Biscuit Norm	Rest	19.1±2.1	0.31±0.05	31.0±3.8
	Stress	20.6±2.3	0.23±0.01	36.6±4.5

- **Significance at 0.05 level ($p < 0.05$) #Approaching significance ($0.05 < p < 0.1$)*
- *NT = Not tested*

Average times for the CAL and normal subjects for the oral and pharyngeal stages of the swallow and the total swallow time with single sips, 100mls and biscuit at rest and post stress. Comparison (paired t test) of times for normal and CAL subjects at rest and after stress for the oral and pharyngeal phases of the swallow and the total swallow time. The CAL and normal subjects both swallowed liquids faster after stress and solids slower.

GRAPHS OF THE MBS TIMES

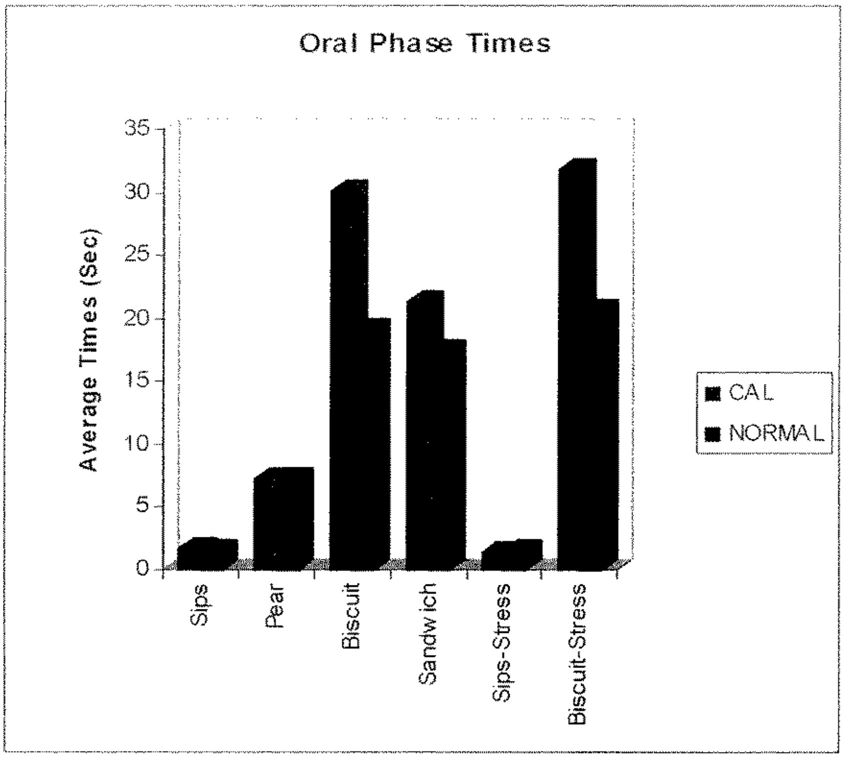


Figure 15. Graph of CAL vs normal average MBS times for the oral phase

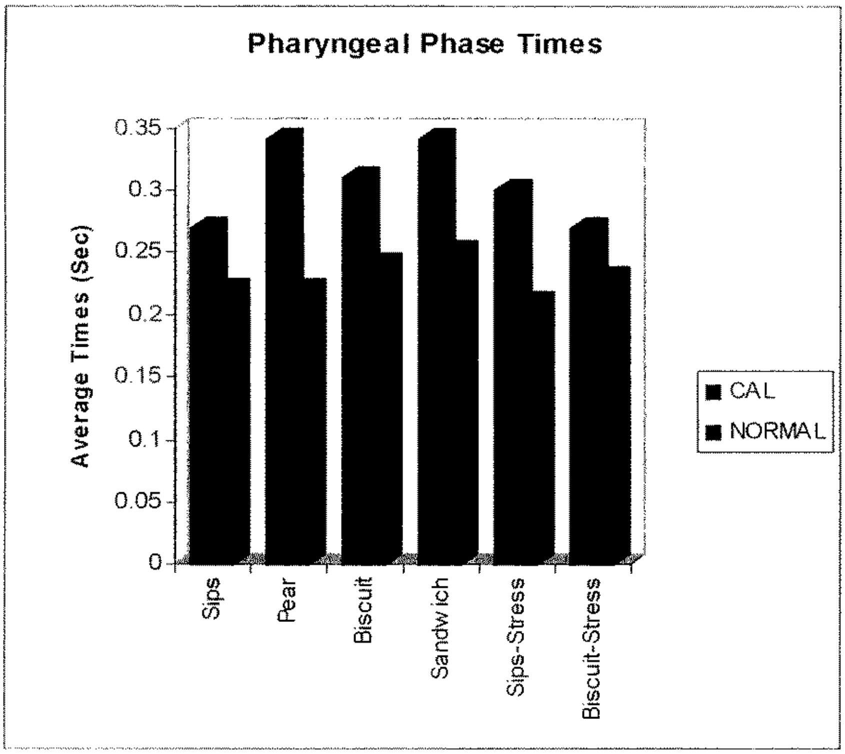


Figure 16 Graph of CAL vs normal average MBS times for the pharyngeal phase

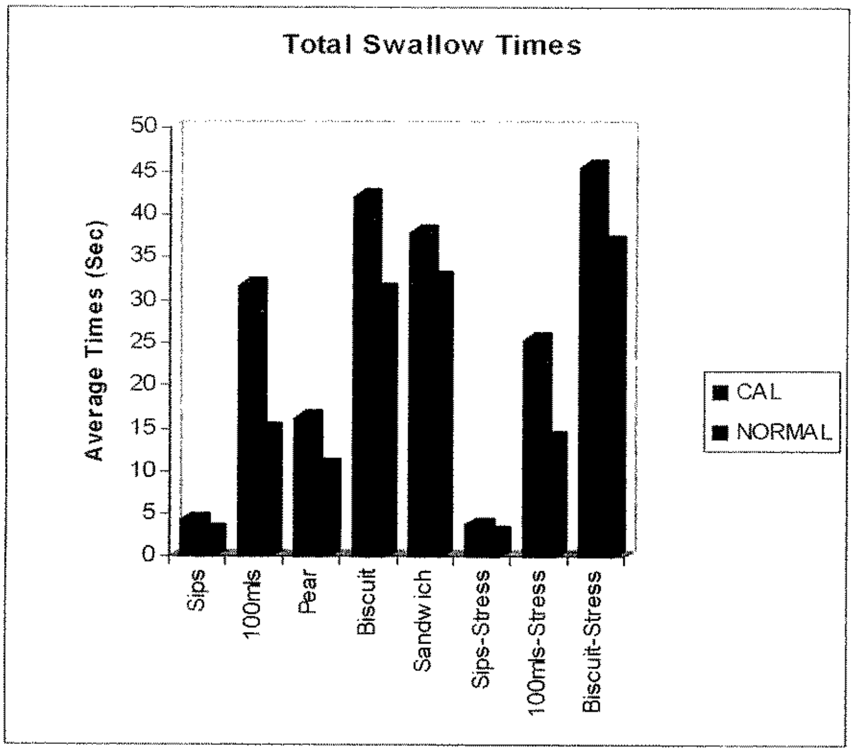


Figure 17. Graph of CAL vs normal average MBS times for the total swallow time

AGE / TIME CORRELATIONS

Age time correlation coefficients were calculated for the normal and CAL subjects. These were to determine if the more severe results were related to age rather than degree of CAL or other factors. There was no correlation between age and the timing results of the CAL subjects. There was a very weak positive correlation for normal subjects at rest on the total time for biscuit at rest (0.55). The same mouthful also had a weak negative correlation for the pharyngeal phase of the swallow (-0.65). After stress the normal subjects showed weak positive correlations for the first sip of 50/50 water/liquid barium for the oral phase (0.54) and the total time (0.53). There were no correlations for the second sip on this consistency for the normal subjects. A summary of the correlation coefficients is provided in table 7.

TABLE 7 - AGE / TIME CORRELATION COEFFICIENTS

CONSISTENCY AND CONDITION		ORAL PHASE	PHARYNGEAL PHASE	TOTAL TIME
Single sips (1)	CAL	-0.16	-0.08	-0.11
Rest	Norm	0.03	-0.50	0.35
Single sips (2)	CAL	0.02	0.03	-0.05
Rest	Norm	-0.33	-0.18	0.12
100mls	CAL	NT	NT	0.29
Rest	Norm	NT	NT	-0.29
Pear (1)	CAL	-0.10	0.32	-0.05
Rest	Norm	0.28	0.35	0.06
Pear (2)	CAL	0.04	0.02	0.23
Rest	Norm	-0.14	-0.33	-0.18
Biscuit	CAL	-0.01	0.20	-0.04
Rest	Norm	0.11	-0.65*	0.19
Sandwich	CAL	0.08	0.42	0.20
Rest	Norm	0.29	-0.30	0.01
Single sips (1)	CAL	-0.40	0.13	0.15
Stress	Norm	0.54*	0.00	0.17
Single sips (2)	CAL	-0.27	0.12	-0.04
Stress	Norm	-0.06	0.01	0.32
100mls	CAL	NT	NT	0.18
Stress	Norm	NT	NT	-0.09
Biscuit	CAL	-0.12	0.21	0.06
Stress	Norm	-0.09	-0.30	0.08

* 95% Confidence interval >0.52

There was no correlation between age and the timing results of the CAL subjects. Correlations for the normal subjects were weak.

SPIROMETRY / TIME CORRELATIONS

There was no correlation between the time taken to swallow liquids or solids and the percent predicted values for the spirometry for the CAL subjects.

QUESTIONNAIRE

The medical questionnaire was used to assess whether subjects met the selection criteria for inclusion in the study (Questions 1 - 13). The chi squared test was used to compare CAL and normal subjects answers to yes/no questions and questions with limited choice answers (Questions 14 - 32). Some questions were dependent on the previous response so were not answered by all the subjects. All 15 normal and 15 CAL subjects undertook the medical and swallowing questionnaires. The results of the swallowing questionnaire follow and are discussed in the order they were presented.

The following three questions will be discussed together as the answers to questions 15 and 16 are dependent on the answer to question 14.

Question 14. Have you had any recent weight loss?

Question 15. Time over which weight loss has occurred?

Question 16. How much weight was lost?

There was no significant difference in reported weight loss between the CAL and normal subjects. One (7%) of the normal subjects reported weight loss of half a kilogram over 1 month. Four (27%) of CAL subjects lost weight with an average of 1.5 kilograms over 9 months.

Questions 17 and 18 are discussed together as the answer to question 18 is dependent on the reply to question 17.

Question 17. Do you have any difficulty swallowing?

Question 18. How long have you had these difficulties?

There was no significant difference between the CAL and normal subjects for reported swallowing difficulties. Two (13%) of the CAL subjects reported swallowing difficulties. One subject reported difficulties over the last 6 months and the other subject reported difficulty swallowing since being gassed in World War Two. One (7%) of normal subjects reported swallowing difficulties which they had been experiencing for the last 12 months. The normal subject specifically reported food getting stuck in the oesophagus. The normal subject who reported difficulty swallowing reported recent weight loss. One of the two CAL subjects who reported difficulty swallowing had also reported weight loss.

Question 19. What type of food do you eat at home?

There was no significant difference between what the CAL and normal subjects ate at home. Of the CAL subjects, 12 (80%) ate a normal diet and three (20%) ate soft or blended food. All of the normal subjects ate a normal diet.

Question 20. Do you have difficulty eating or drinking any of the following? (steak, dry biscuits, cereal, bread, salads, nuts, corn, vegetable soup, water, tea, coffee, soft drink.)

The CAL subjects reported difficulty with both foods and liquids. The normal subjects reported difficulty with textured and dry foods only. Eight (53%) CAL subjects had difficulty with food of some type. Three had difficulty with steak, 4 had difficulty with nuts, three had difficulty with biscuits, two had difficulty with corn, two had difficulty with salads and one had difficulty with cereal. Three (20%) CAL subjects reported difficulty with liquid. They all reported problems with water, tea, coffee and soft drink. Four (27%) of the normal subjects reported difficulty with foods. Two had difficulty with steak, two had difficulty with nuts, one with cereal and one with biscuit. Overall problem foods were more common in the CAL subjects and problems with liquids only occurred in the CAL subjects.

Question 21. Do you have to chew your food extremely well?

There was no significant difference between the CAL and normal subjects in how much they reported they chewed their food. Nine (60%) of the normal subjects and 8 (53%) of the CAL subjects reported chewing their food well.

Question 22. Do you cut your food into small pieces?

There was a very significant difference between CAL and normal subjects on question 22 with the CAL subjects reporting cutting their food into small pieces more frequently. Nine (60%) of CAL subjects and none of normal subjects reported cutting their food into small pieces ($p < 0.01$).

Question 23. Do you eat quickly, at a steady pace or slowly?

There was a significant difference between the CAL and normal subjects in the rate they reported to eat with CAL subjects reporting eating slowly more frequently. Seven (47%) of CAL subjects and two (13%) of the normal subjects reported eating slowly ($p<0.05$).

Question 24. Do you drink quickly, at a steady pace or slowly?

There was a significant difference between the CAL and normal subjects in the rate they reported drinking with CAL subjects reporting drinking slowly more frequently. Six (40%) of CAL subjects and 1 (7%) of normal subjects reported drinking slowly ($p<0.05$).

Question 25. Do you cough when drinking?

A significantly higher proportion of CAL subjects, 6 (40%), coughed when drinking once a month or more compared to none of the normal subjects ($p<0.01$).

Question 26. Do you cough when eating?

There was no significant difference between the CAL and normal subjects for coughing when eating. Two(13%) of the CAL subjects and 1(7%) of the normal subjects reported coughing when eating once a month or more.

Question 27. Do you choke when drinking?

There was no significant difference between the CAL and normal subjects for choking when drinking. Two (13%) of the CAL subjects and none of the normal subjects reported for choking when drinking once a month or more.

Question 28. Do you choke when eating?

There was no significant difference between the CAL and normal subjects for choking when eating. Two (13%) of the CAL subjects and none of the normal subjects reported choking when eating once a month or more.

Question 25 and 27 were analysed together.

The CAL subjects reported very significantly more coughing or choking when drinking ($p<0.01$). Seven (47%) of the CAL subjects and none of the normal subjects reporting coughing or choking when drinking once a month or more.

Questions 26 and 28 were analysed together.

Four (27%) of CAL subjects and one (7%) of normal subjects reported coughing or choking when eating once a month or more. The CAL and normal subjects were not significantly different for coughing or choking when eating.

Questions 29. Do you have difficulty swallowing tablets?

There was no significant difference between the CAL and normal subjects for ability to swallow tablets. Four (27%) of the CAL subjects and three (20%) of the normal subjects reported difficulty swallowing tablets.

Question 30. Does food or drink ever go up your nose?

There was no significant difference between the CAL and normal subjects for nasal regurgitation. Three (20%) of the CAL subjects and one (7%) of the normal subjects reported nasal regurgitation.

Question 31. How often does this occur?

Both the CAL and normal subjects reported nasal regurgitation occurred once a month or less.

Question 32. Do you clear your throat when you eat or drink?

There was no significant difference between the CAL and normal subjects for throat clearing. Five (33%) of the CAL subjects and two (13%) of the normal subjects reported throat clearing when eating or drinking.

TABLE 8 - SWALLOWING QUESTIONNAIRE

QUESTION	CAL %	NORMAL %	P VALUES
QUESTION 14. (Lost weight)	yes = 27% (4) no =73% (11)	yes = 7% (1) no = 93% (14)	0.14
QUESTION 17. (Diff. Swallowing)	yes = 13% (2) no =87% (13)	yes = 7% (1) no =93% (14)	0.54
QUESTION 19. (Diet)	soft/blend = 20% (3) normal = 80% (13)	soft/blend = 0% (0) normal = 100% (15)	0.07
QUESTION 21. (chew well)	yes = 53% (8) no =47% (7)	yes = 60% (9) no =40% (6)	0.71
QUESTION 22. (cut small pieces)	yes = 60% (9) no = 40% (6)	yes = 0% (0) no = 100% (15)	0.001
QUESTION 23. (eating rate)	slow = 47% (7) steady/quick = 53% (8)	slow = 13% (2) steady/quick = 87% (13)	0.046
QUESTION 24. (drinking rate)	slow = 40% (6) steady/quick = 60% (9)	slow = 7% (1) steady/quick = 93% (14)	0.03
QUESTION 25. (cough drink)	yes = 40% (6) no = 60% (9)	yes = 0% (0) no = 100% (15)	0.006
QUESTION 26. (cough eat)	yes = 13% (2) no = 87% (13)	yes = 7% (1) no = 93% (14)	0.54
QUESTION 27. (choke drink)	yes = 13% (2) no = 87% (13)	yes = 0% (0) no = 100% (15)	0.14

QUESTION 28. (choke eat)	yes = 13% (2) no = 87% (13)	yes = 0% (0) no = 100% (15)	0.14
QUESTION 29. (diff. Tablets)	yes = 27% (4) no = 73% (11)	yes = 20% (3) no = 80% (12)	0.67
QUESTION 30. (up nose)	yes = 20% (3) no = 80% (12)	yes = 7% (1) no = 93% (14)	0.28
QUESTION 32. (throat clear)	yes = 33% (5) no = 67% (10)	yes = 13% (2) no = 87% (13)	0.20
QUESTION 25 & 27 (cough/choke drink)	yes = 47% (7) no = 53% (8)	yes = 0% (0) no = 100% (15)	0.003
QUESTION 26 & 28 (cough/choke eat)	yes = 27% (4) no = 73% (11)	yes = 7% (1) no = 93% (14)	0.14

Comparison of CAL and normal subjects for the swallowing questionnaire. P values were determined by chi squared tests.

PREDICTIONS MADE BY THE QUESTIONNAIRE

Comparisons were made between answers to questions which might be predictive of results on the modified barium swallow. Questions 23 and 24 predicted that subjects with CAL would eat and drink slowly. This was found to be the case on the timed analysis of the modified barium swallow. Questions 25 and 27 (cough/choke - liquids) was compared to aspiration of liquids. The sensitivity was 0.4 and the specificity was 0.5 for coughing or choking once a month or more. If the analysis was done for less than once a month the sensitivity decreased to 0.2 and the specificity increased to 0.7. Questions 26 and 28 (cough/choke - solids) were compared to aspiration of solids. The sensitivity was 1 and the specificity was 0.8 for coughing or choking once a month or more. If the analysis was done for less than once a month the sensitivity decreased to zero and the specificity increased to 0.9. In general questions 25 and 27 and questions 26 and 28 were poor predictors of aspiration with subjects only reporting coughing once a month or more, which is not frequent enough to detect those who did aspirate.

Question 21(chew your food well) and question 22 (cut into small pieces) was compared to chewing problems on the modified barium swallow. The sensitivity for question 21 was 0.6 and the specificity 0.5, the sensitivity for question 22 was 0.6 and the specificity 0.3. Neither of these questions were an accurate predictor of chewing problems on the modified barium swallow.

Question 30/31 was not compared with the modified barium swallow as no nasal regurgitation was seen on any of the normal or CAL subjects.

Question 32 (throat clear) was compared with aspiration of solids or liquids. The sensitivity was 0 and the specificity was 0.6. This question does not predict aspiration at all.

The other questions were not suitable for direct comparison with the modified barium swallow. In general CAL subjects were poor predictors of their own swallowing problems using the swallowing questionnaire.

BEDSIDE EXAMINATION

The chi squared test was used to compare the results of the bedside examination where the answers were categorical in nature. The results for the bedside examination will be discussed in the order the test was conducted.

Airway protection mechanisms

There was a very significant difference between the CAL and normal subjects for vocalisation with two (13%) normal subjects having a weak and /or hoarse voice and 14 (93%) CAL subjects ($p<0.01$). There was no significant difference for voluntary cough, reflexive cough or throat clear.

TABLE 9 - BEDSIDE EXAMINATION (AIRWAY PROTECTION MECHANISMS)

AIRWAY PROTECTION	CAL %	NORMAL %	P VALUES
Voluntary cough	Weak =13% (2) Adequate/strong = 87% (13)	Weak = 0% (0) Adequate/strong = 100% (15)	0.14
Reflexive Cough	Weak = 13% (2) Adequate/strong = 87% (13)	Weak = 0% (0) Adequate/strong =100% (15)	0.14
Vocalisation	Weak/hoarse = 93% (14) Strong = 7% (1)	Weak/hoarse =13% (2) Strong = 87% (13)	0.001
Throat clear	Effective = 87% (13) Not effective =13% (2)	Effective =100% (15) Not effective = 0% (0)	0.14

Comparison of CAL and normal subjects for the bedside examination, airway protection mechanisms. P values were determined by chi squared tests.

Oromusculature assessment

All the normal and CAL subjects had a normal cranial nerve assessment.

Food tolerance

Oral phase

Spillage from lips.

Two CAL subjects had spillage from the lips, 1 on liquid and one on biscuit. No normal subject had spillage from the lips. There was no significant difference between the CAL and normal subjects.

Bolus formation.

All CAL and normal subjects were able to form a bolus.

Tongue Pumping.

No normal or CAL subject demonstrated tongue pumping.

Mouth clearing.

Two CAL subjects had difficulty clearing the oral cavity, one on biscuit and one on both biscuit and sandwich. One normal subject had difficulty clearing sandwich. There was no significant difference between the CAL and normal.

Pharyngeal phase

Delayed initiation of the swallow.

Six CAL subjects had a delayed swallow, 4 on all consistencies, one on liquid alone and one on liquid and biscuit. No normal subject had delayed initiation of the swallow. The CAL subjects had a very significantly delayed initiation of the swallow compared to the normal subjects ($p<0.01$).

Multiple swallows to clear bolus.

Five CAL subjects used multiple swallows, two on biscuit, one on liquid, fruit piece with syrup and biscuit, one on liquid, sandwich and biscuit and one on liquid alone. None of the normal subjects used multiple swallows. The CAL subjects used multiple swallows significantly more than the normal subjects ($p<0.05$).

Unable to initiate swallow.

All CAL and normal subject were able to initiate a swallow.

'Gurgly' phonation following swallow.

Two CAL subjects had gurgly voices on liquids. None of the normal subjects had gurgly voices on any consistency. There was no significant difference between the CAL and normal subjects for 'gurgly' phonation.

Coughing before swallowing.

Neither the normal or CAL subjects coughed before swallowing.

Coughing during swallowing.

One CAL subjects coughed during swallowing a piece of sandwich. No normal subject coughed during swallowing. There was no significant difference between the CAL and normal subjects.

Coughing after swallowing.

Eight CAL subjects coughed after the swallow. One coughed on liquid, capsule and sandwich, one on liquid and biscuit, one on pear piece with syrup and biscuit, one on liquid and biscuit, one on liquid and capsule, one on biscuit and two on liquid alone. No normal subject coughed after swallowing. The difference between the CAL and normal subjects on coughing after swallowing was very significant ($p<0.01$).

Coughing before, during or after swallowing.

These were analysed together as detection of an aspiration event is clinically significant even if the timing of the aspiration event is unable to be determined at bedside. Nine CAL subjects coughed compared with one normal subject. There was a very significant difference between the CAL and normal subjects for coughing before, during or after the swallow ($p<0.01$).

Coughing on liquids

Six CAL subjects and one normal subject coughed when swallowing liquids. There was a significant difference between the CAL and normal subjects for coughing when swallowing liquids ($p<0.05$).

Coughing on solids

Five CAL subjects coughed on solids and no normal subject. There was a significant difference between the CAL and normal subjects for coughing on solids ($p<0.05$).

Decreased laryngeal elevation.

No CAL or normal subject was reported to have decreased laryngeal elevation.

TABLE 10 - BEDSIDE EXAMINATION (FOOD TOLERANCE)

SWALLOW FEATURE	CAL %	NORMAL %	P VALUES
Spillage from lips	yes = 13% (2) no = 87% (13)	yes = 0% (0) no = 100% (15)	0.14
Inability to form bolus	yes = 0% (0) no = 100% (15)	yes = 0% (0) no = 100% (15)	ND
Tongue pumping	yes = 0% (0) no = 100% (15)	yes = 0% (0) no = 100% (15)	ND
Unable to clear mouth	yes = 13% (2) no = 87% (13)	yes = 7% (1) no = 93% (14)	0.54
Delayed initiation	yes = 40% (6) no = 60% (9)	yes = 0% (0) no = 100% (15)	0.006
Decreased laryngeal elevation	yes = 0% (0) no = 100% (15)	yes = 0% (0) no = 100% (15)	ND
Multiple swallows	yes = 33% (5) no = 67% (10)	yes = 0% (0) no = 100% (15)	0.01
Gurgly phonation	yes = 13% (2) no = 87% (13)	yes = 0% (0) no = 100% (15)	0.14
Cough before swallow	yes = 0% (0) no = 100% (15)	yes = 0% (0) no = 100% (15)	ND
Cough during swallow	yes = 7% (1) no = 93% (14)	yes = 0% (0) no = 100% (15)	0.31
Cough after swallow	yes = 53% (8) no = 47% (7)	yes = 7% (1) no = 93% (14)	0.005
Cough before / during / after swallow	yes = 60% (9) no = 40% (6)	yes = 7%(1) no = 93% (14)	0.002
Cough liquid	yes = 40% (6) no = 60% (9)	yes = 7% (1) no = 93% (14)	0.03
Cough solid	yes = 33% (5) no = 67% (10)	yes = 0% (0) no = 100% (15)	0.01

ND = No difference.

Comparison of CAL and normal subjects for the bedside examination food / fluid trial. P values were determined using chi squared tests.

PREDICTIONS MADE BY THE BEDSIDE EXAMINATION

Several aspects of the bedside examination were compared with the results of the modified barium swallow to determine whether the bedside examination could predict the results of the modified barium swallow for the CAL subjects. Multiple swallows were compared with piecemeal deglutition and delayed initiation with the onset of the pharyngeal phase. The sensitivity for these comparisons was less than 0.5 for all consistencies and the specificity varied from 0 to one. Therefore multiple swallows were a poor predictor of piecemeal deglutition and delayed initiation was a poor predictor of delayed onset of the pharyngeal phase.

Coughing before the swallow was compared with aspiration before the swallow, coughing during the swallow with aspiration during the swallow and coughing after the swallow with aspiration after the swallow. The sensitivity was zero for all but one comparison and the specificity was between 0.7 and one. Coughing after versus aspiration after for 100mls of liquid had a sensitivity of one and a specificity of 0.7. These comparisons showed that the bedside examination was not sensitive enough to predict the time when aspiration occurred during the swallow but it was thought if taken together it might be able to predict which individuals aspirated on which consistencies. Therefore coughing before, during or after the swallow was compared with aspiration before, during or after the swallow. For single sips the sensitivity was 0.5 and the specificity 0.8, for 100mls of liquid the sensitivity was 0.7 and the specificity 0.8 and for biscuit the sensitivity was 0 and the specificity 0.8. These were the only consistencies on which aspiration occurred on the modified barium swallow. This improved the predictive value of the bedside examination but still appeared to be too specific. Therefore the comparisons were limited to coughing before, during or after the swallow and aspiration of solids or liquids. The sensitivity for liquids was one and the specificity 0.9, for solids the sensitivity was one and the specificity was 0.8. This was now a useful measurement for the detection of aspiration but is not specific for the consistency and time of aspiration. Aspiration may also be detected by a gurgly voice quality. The sensitivity was 0.2 and the specificity 0.8. Gurgly voice quality was a poor predictor of aspiration.

Other aspects of the bedside examination were not compared as their equivalent feature was not seen in any of the CAL subject's modified barium swallows.

DISCUSSION

In this study, we compared the swallowing function of 15 subjects with CAL to 15 healthy age matched controls. Analysis of the clinical features and timing of swallowing events on the MBS were completed. A swallowing questionnaire and bedside examination were also conducted to demonstrate differences between the CAL and normal subjects and to determine their predictive value.

The control group was found to have normal swallows with some mild changes that are consistent with normal ageing. In contrast, a spectrum of abnormalities was seen in the CAL subjects, placing them at increased risk of aspiration and other complications such as malnutrition. All the CAL subjects had one or more abnormal features.

A detailed discussion of the results of the modified barium swallows follows. The dysphagic features seen in the majority of CAL subjects were, in the oral phase, difficulty chewing solids and piecemeal deglutition. In the pharyngeal phase, vallecular residue and a delayed onset of the pharyngeal phase of the swallow were prevalent. Laryngeal penetration on liquids occurred in most CAL subjects, which in one third of subjects lead to aspiration. This aspiration was often silent with no reflexive cough initiated increasing the risk of pulmonary complications. In a small number of cases they also had difficulty with bolus formation, pyriform sinus, posterior pharyngeal wall and hypopharyngeal residue. Aspiration of biscuit particles occurred in one subject. Aspiration only occurred in the CAL subjects over 80 years old. One possible explanation is that the older subjects were unable to compensate for their swallowing impairment. The younger subjects, although having similar impairments, were able to compensate and prevent aspiration at least during the short time of the modified barium swallow (28). Increasing age is associated with reduced swallowing efficiency and thus reserve capacity. In the older subjects their reserve capacity was exceeded by their swallowing impairments (36).

The clinical picture for the normal subjects is very different to the CAL subjects. The normal subjects had no difficulty with chewing or bolus formation. Mild piecemeal deglutition was common. This is consistent with normal ageing (42). A mild delay in the initiation of the pharyngeal phase of the swallow and occasional transient laryngeal penetration above the level of the cords occurred in a number of normal subjects. A mild delay in the initiation of the swallow is reported in the normal ageing literature (40). Transient laryngeal penetration although not reported in the literature is consistent with clinical findings in this age group. A small number of subjects occasionally experienced vallecular residue and pyriform sinus residue. Some retention of the bolus in the valleculae has been reported to occur with increasing age however there are no reports of pyriform sinus residue(28). It is interesting to note that the two normal subjects who had pyriform sinus residue had the poorest FEV1 of the normal subjects and the worst general health.

There are a number of features of the modified barium swallows that suggest individuals with CAL are at increased risk of aspiration generally even when aspiration is not demonstrated. Five independent predictors of aspiration have been reported: vallecular stasis, reduced hyoid elevation, diffuse hypopharyngeal stasis, delayed initiation of the pharyngeal phase of the swallow and deviant epiglottic function. As the severity of the first four variables increases, the proportion of individuals who aspirate also increases (106, 122). Vallecular stasis and a delayed initiation of the swallow were commonly reported in the CAL subjects and diffuse hypopharyngeal stasis in a small number of subjects. The probability of aspiration occurring is therefore greater in the CAL subjects particularly when more than one variable occurs simultaneously and where the rating was severe. When making a decision about oral intake, both frank aspiration and predictors of aspiration should be considered.

Vallecular residue has been reported as a consequence of oral dysphagia (122). Of the nine CAL subjects who had vallecular residue seven also had difficulty chewing.

Modification of the individual's diet by reducing its texture may be an appropriate therapeutic measure.

The time taken for the oral and pharyngeal phases of the swallow and the total swallow time were calculated for the MBS. The CAL subjects demonstrated a significant increase in the total time taken to swallow a single mouthful of liquid, 100mls of liquid and a mouthful of pear piece with syrup at rest. Significant increases in the oral phase time for biscuit at rest, the pharyngeal phase for pear piece at rest and the pharyngeal phase for a single mouthful of liquid after stress were also seen.

The increased duration of the oral phase when eating biscuit appeared to be due to difficulty co-ordinating breathing and mastication. The increased duration of the pharyngeal phase on both pear piece (at rest) and single sips of liquid (after stress) was an unexpected result. The implication is that a longer swallowing apnoea is necessary to ensure pharyngeal contents are not inhaled. This may be a potential source of aspiration (122a).

The increased duration of the total swallow times were probably due to a combination of factors including multiple swallows to clear a mouthful of liquid, problems chewing textured solids and difficulty co-ordinating mastication and the initiation of the swallow with respiration. These results suggest that patients with CAL will take longer to eat and drink which may result in decreased oral intake compromising their nutritional status. Malnutrition is a well recognised feature of the CAL population (83, 84, 85, 86, 87, 88).

The questionnaire was generally a poor predictor of the swallowing function of the CAL subjects. A small number of questions showed a significant difference between the CAL and normal subjects. For instance, on question 22 "Do you cut your food into small pieces?" a significant proportion of the CAL subjects reported cutting their food into small pieces compared to the normal subjects. Interestingly they did not report modifying the texture of their diet by eating soft or blended foods or chewing food extremely well. Although the modified barium swallow reported the CAL subjects had difficulty chewing biscuit and sandwich this was not strongly predictive of those individuals who cut their food into small pieces. The prevalence of chewing difficulty in the CAL subjects and the lack of self modification suggests that advice on dietary modification of texture would be an appropriate clinical application of the study results.

Questions 23 and 24 "Do you eat and do you drink quickly, at a steady pace or slowly?" showed significantly more of the CAL subjects ate and drank slowly. This is reflected in the timing analysis which generally showed swallowing of solids and liquids to be slower. This appears to be a useful question to ask in an initial clinical consultation.

Question 25 and 27 "Do you cough or choke when drinking?" showed a very significant difference between the CAL and normal subjects. When compared with instances of aspiration on the MBS they had poor predictive value. One possible explanation is that aspiration is occurring intermittently. Many of the subjects who reported coughing may not have aspirated in the test condition, as it is such a small sample of swallowing function. Alternatively aspiration may frequently be silent with no coughing occurring and therefore not reported. Certainly the high instance of silent aspiration on the MBS supports this supposition.

The bedside examination assessed airway protection mechanisms, cranial nerve function and swallowing function during a food and fluid trial. The results of the cranial nerve assessment were normal for all the normal and CAL subjects. The examination of airway protection mechanisms found a very significant difference between the CAL and normal subjects for vocalisation. The CAL subjects had weak/hoarse voices. Abnormal phonation quality, harsh phonation and breathy phonation have been associated with subglottic penetration (123). The exact relationship between phonation quality and swallowing function in CAL subjects is not clear. Good vocal closure is known to be an integral part of airway closure during the swallow (5, 16).

The food/fluid trial demonstrated significant differences between the CAL and normal groups for the prevalence of delayed initiation of the swallow and multiple swallows. These results were not predictive of the equivalent modified barium swallow clinical features. There were significant differences on coughing after the swallow, coughing before, during or after the swallow and coughing on solids and liquids. Of these, coughing on liquids and solids were the most useful in predicting aspiration on the modified barium swallow. The timing of aspiration and consistency could not be accurately predicted from the bedside assessment.

There are a limited number of studies in the literature examining swallowing function in the CAL population. Stein et al found cricopharyngeal dysfunction to be the key dysphagic finding (100). In contrast, our study found cricopharyngeal dysfunction was infrequent and at a similar rate to the normal controls. Coelho reported a range of dysphagic symptoms including aspiration, difficulty with bolus formation and control, delayed swallow and problems with lingual and pharyngeal peristalsis (90). The problem with this study was that 13 of the 14 subjects tested had a tracheostomy. Tracheostomy is known to potentially interfere with the swallow (91, 92, 93, 94, 95, 96, 97, 98, 99). The swallowing dysfunction they reported is unable to be clearly attributed to either the effect of the CAL or the tracheostomy. The importance of our study is that it confirms significant swallowing problems independent of tracheostomy in the CAL population. Our study supports their findings of aspiration, difficulty with bolus formation and a delayed swallow but not problems with lingual and pharyngeal peristalsis.

The cause of dysphagia in the CAL subjects is not clear. Possible explanations include an inability to co-ordinate the swallow and respiration due to dyspnoea and desensitisation of the pharynx and larynx due to the trauma of chronic cough or the effect of medication. There is some evidence to suggest that co-ordination of respiration is a key component. The pattern of respiration found in those with CAL differs from that seen in the normal population. Normal subjects begin to swallow during expiration, have a short period of apnoea and recommence respiration with an expiration. Individuals with CAL more frequently commence the swallow during inspiration, followed by the swallowing apnoea and recommence respiration with inspiration (54). Commencing the swallow in inspiration decreases bolus control and may explain the high incidence of material reaching the vallecular and pyriform sinuses before the commencement of the pharyngeal phase of the swallow. On completion of the swallow recommencing respiration with inspiration increases the risk of post swallow aspiration. The pooling seen in the vallecular would be more likely to be aspirated in this case.

Difficulty co-ordinating respiration and chewing resulted in incomplete mastication of textured foods in the CAL subjects. Large particles and sometimes whole pieces of food were swallowed. The particulate matter may then be inhaled as seen in one of the CAL subjects where a fragment of biscuit was drawn into the larynx. Whole pieces potentially obstruct the airway if aspirated and are more likely to become lodged in the pharynx.

The delayed onset of the swallow, pharyngeal pooling and high incidence of silent aspiration suggests some alteration in sensory function. Whether the changes are due to the trauma of the frequent coughing associated with CAL, medication or some other mechanism is not yet clear. A combination of altered sensation and difficulty co-ordinating swallowing and respiration seems the most likely explanation.

The observations of this study were limited by the small sample size however it reflects the number of CAL subjects available through Concord Repatriation General Hospital who met the selection criteria. The elimination of those volunteers with neurological disease and the need for recurrent infective exacerbations excluded many subjects. In this age group a previous CVA or dementia were not uncommon.

Consequently a larger sample of CAL patients may have provided a more consistent pattern of feeding.

This study potentially has some sampling error as only one of each type of assessment was able to be conducted. The MBS was limited to one because of the need to minimise radiation exposure. In this way however the study replicated clinical practise in which management is frequently based on an initial bedside assessment and MBS. For this reason the predictive value of the bedside examination is essential.

The MBS was a suitable assessment tool for both the CAL and normal subjects. The testing of different consistencies and multiple attempts at any given consistency on the MBS was limited by the need to minimise radiation exposure. The different types of abnormalities seen with the range consistencies suggest that variety is important and the consistencies trialed were appropriate. It is uncertain what value might be achieved from studying further food types, bearing in mind that the longer the test the more radiation and the less practical for all. The MBS projects angle was limited by radiation exposure times hence the sole use of the lateral projection, which is the most sensitive to a wide range of abnormalities.

Several subjects were unable to complete the testing in the stress condition due to aspiration at rest and increasing respiratory distress. Continuous drinking was also difficult to rate after stress as a number of the CAL subjects were unable or refused to drink in a continuous manner. This meant we were unable to demonstrate aspiration in these subjects although we felt that many of them would have aspirated if they had drunk in continuous manner.

The rating scale used to measure shortness of breath was problematic in this population. A large number of the subjects were unfamiliar with ratings scales in general and found their use a new and confusing concept. Although all the subjects were more short of breath after stress, the rating scale was probably not a true reflection of the individuals degree of shortness of breath for many of the subjects.

Directions for future study could include investigation of other populations with respiratory disease including asthma, cystic fibrosis, influenza, and lung carcinoma. Study of swallowing function during different stages of an acute exacerbation of CAL would be worthwhile. Investigations could utilise not only videofluroscopy but nasendoscopy, simultaneous measurement of respiratory patterns and scintigraphy. Comparisons of populations who cough (cystic fibrosis) with those who have only dyspnoea (pulmonary vascular disease) may help clarify whether the cause of swallowing problems is the effect of chronic cough or shortness of breath.

Further investigation is needed into sensation in the oropharynx and larynx for individuals with CAL. The impact of medication in particular inhaled corticosteroids is needed. This has implications for other populations using these types of medication. The impact of repeated coughing on both sensation and motor function needs to be determined. The relationship between dyspnoea and swallowing function needs further clarification. This has implications for those with acute respiratory illness and whether they should be fed orally in the initial stages of an acute episode. A simple guideline, for example of breaths per minute, which makes swallowing unsafe, would be a useful for clinical practise.

CONCLUSION

This study confirms that individuals with CAL have impaired swallowing function that may lead to aspiration. This supports our hypothesis that aspiration of pharyngeal contents may be a precipitating factor in the development of acute exacerbations of CAL. The impact of dysphagia on their ability to maintain nutrition is not known, though work in other areas suggests that dysphagia may contribute to malnutrition (89). This is of particular importance given the magnitude of this problem in the CAL population (83, 84, 85, 86, 87, 88).

This study suggests that a MBS is an essential part of assessing individuals suspected of swallowing dysfunction. The assessment needs to include a range of consistencies. Thin fluids taken in single sips and continuously, pear piece with syrup and biscuit were found to be particularly useful in identifying swallow problems. The use of a respiratory stressor may in some cases help to demonstrate suspected problems related to dyspnoea.

The bedside examination is useful in selecting those who need an MBS study by identifying those at risk of aspiration. It is unable to provide specific details on when aspiration is occurring and other clinical features that put the individual at risk of aspiration. Useful questions to ask in an initial assessment are: "Do you eat or drink slowly?" and "Do you cough or choke when drinking?". Identification of nutritional problems is also important at this initial stage.

Recommendations based on the MBS and bedside examination are likely to include modification of the texture of the diet, avoiding dry particulate matter, the use of thickened fluids in some cases, postural changes and alterations in the quantity of food and drink taken on any occasion.

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GLOSSARY OF TERMS

apnoea:	transitory cessation of breathing
aspiration:	entry of material into the laryngeal vestibule passing through and below the vocal cords
dyspnoea:	difficult or laboured breathing
FEV1:	forced expiratory volume in one second
hypercapnia:	raised carbon dioxide tension in the arterial blood
hyperpnoea:	rapid, deep breathing; panting; gasping
hyperventilation:	increased breathing
hypoventilation:	diminished breathing or under ventilation
hypoxaemia:	diminished amount of oxygen in the arterial blood
hypoxia:	diminished amount of oxygen in the tissues
laryngeal penetration:	entry of material into the laryngeal vestibule above the level of the vocal cords
pack year:	20 cigarettes a day smoked for 1 year
silent aspiration:	aspiration which occurs without a reflexive cough being stimulated
tachypnoea:	abnormal frequency of respiration
tidal volume:	the amount of air which moves in and out of the lungs during normal breathing

APPENDIX

APPENDIX A

AGE RELATED CHANGES TO THE ORAL PREPARATORY AND ORAL PHASES OF SWALLOWING

GENERAL CHANGES	SPECIFIC CHANGES	FUNCTIONAL OBSERVATIONS
size and structural changes to muscles including: *reduction in muscle mass(32) *decrease in size of fast-twitch fibres(type2) (31) *decrease in number of functioning muscle motor units(30) *increase in the size of remaining muscle motor units(30)	*increased fatty and connective tissue in tongue (27) *dysfunction of tongue suspensory muscles (124, 125)	*decreased masticatory strength (27) *poor mastication of the bolus (36) *additional tongue movements (38) *poor bolus control and propulsion (39) *slow oral phase (38, 41) *decreased peak suction pressure on multiple sips from a straw (42) *bolus held posteriorly pre-swallow (38, 40) *ptosis of the tongue (28)
*general decrease in bone density particularly in ageing female due to bone reabsorption (36)	*alveolar ridge reabsorption which results in poorly fitting dentures which in turn causes tempromandibular dysfunction (36)	*decreased masticatory strength (27) *poor mastication of the bolus (36) *slow oral phase (41, 38)

*decrease in amount of saliva produced (36) *saliva becomes more viscous (36) *reduction in enzyme activity by up to 75 % (126)	*poor lubrication of surfaces of oral tissues which allows material to move in and around the oral cavity for mastication and bolus formation (36) *decreased breakdown of material in the oral cavity due to the reduction in enzyme activity(126)	*poor mastication of the bolus (36) *slow oral phase (41, 38) *additional tongue movements (15) *increased difficulty with bolus formation and propulsion(39) *less spontaneous swallows(15)
*atrophic taste buds (127)	*decrease in taste sensation (36)	*may impact on bolus formation and propulsion due to decreased awareness of bolus
*decreased two point discrimination on the lateral tongue and floor of mouth but not the tongue tip (33)		*may impact on mastication, bolus formation and propulsion due to decreased awareness of position and consistency of bolus

APPENDIX B

AGE RELATED CHANGES TO THE PHARYNGEAL PHASE OF SWALLOWING

GENERAL CHANGES	SPECIFIC CHANGES	FUNCTIONAL OBSERVATIONS
*slower response to afferent stimuli particularly when complex movement required (35) The actual processing of stimuli is the same(128)		*delayed initiation of the swallow (41,40) *delayed initiation of the hypolaryngeal excursion (41)
*decrease in the sensory capacity of the laryngopharynx (34)(34a)		*increased volume needed to stimulate swallow (38) *increased risk of silent aspiration (28, 129, 34a)
*changes in structure and function of muscles(see previous table for details)	*the pharyngeal phase is effected not only by the muscles involved in this phase but also the muscles in the oral phases (For example: a decrease in the pumping action of the tongue due to changes in muscle function will alter the rate at which the bolus is propelled through the pharynx) *lack of connective tissue support of larynx and hyoid (28) *drop in the position of the larynx and hyoid putting increased stretch on muscles and ligaments	* increased pharyngeal contraction on liquids and solids (44) *increased pressure wave amplitude and duration in hypopharyx on liquid (131) *increased frequency of multiple swallows for a single mouthful (42) *increased frequency of polyphasic laryngeal movements (42) *increased pharyngeal transit duration (41) *diminished larynx/hyoid elevation (28) *impaired laryngeal closure (laryngeal penetration (43)

	(28,) *increase in fatty deposits and atrophy of intrinsic laryngeal muscles (28, 130) *laxity and atrophy of muscle and connective tissue boundaries leading an enlarged pharyngeal cavity (28) *diminished pharyngeal constrictor function (28)	*retention of bolus in the valleculae (28)
*changes in structure and function of sphincters (41,15)	*reduced cross - sectional area during cricopharyngeal sphincter opening (15) *decreased cricopharyngeal resting pressure (15)	*increased duration of cricopharyngeal sphincter opening (41)
*changes in bone /cartilage structures (132)	*osteophites (132) *straight or curled epiglottis (132)	*may or may not be symptomatic depending on the size of the osteophites and the size and structural proportions of the pharynx/larynx. May impede the normal flow of the bolus through the pharynx and prevent inversion of the epiglottis (132) *valleculae may be covered and bolus directed towards larynx (132)

APPENDIX C

SWALLOWING QUESTIONNAIRE

BIOGRAPHICAL INFORMATION

NAME:____

ADDRESS:______________________________________

____

PHONE NUMBER:________________________________

MEDICAL RECORDS NUMBER:________________________

DATE OF BIRTH:________________________________

LMO:____

AMO:____

ADMITTING DIAGNOSIS:___________________________

DATE ADMINISTERED:____________________________

MEDICAL HISTORY

GASTROESOPHAGEAL MEDICAL HISTORY

1.Do you or have you ever had any of the following gastroesophageal disorders?
(Please circle)

reflux	YES/NO/EVER________________
hiatus hernia	YES/NO/EVER________________
Motility disorder	YES/NO/EVER________________
achalasia	YES/NO/EVER________________
diverticulum	YES/NO/EVER________________
oesophagitis	YES/NO/EVER________________
cancer of oesophagus	YES/NO/EVER________________
other____________	YES/NO/EVER________________

2.Have you had any gastric surgery? YES/NO

What type of surgery did you have?________________________

When did you have the surgery?________________________

3.Do you experience any of the following on a regular basis?(Please circle)

heart burn	YES/NO
regurgitation of undigested food (not vomiting)	YES/NO
acid regurgitation	YES/NO
frequent belching during meals	YES/NO
a feeling that food is stuck / wont go down	YES/NO
pain on swallowing	YES/NO
a hoarse voice	YES/NO
chest pain after eating	YES/NO
a sour taste in your mouth	YES/NO

RESPIRATORY MEDICAL HISTORY

4.Do you or have you had any of the following respiratory illnesses?(Please circle)

asthma	YES/NO/EVER____________________
bronchitis	YES/NO/EVER____________________
CAL	YES/NO/EVER____________________
pneumonia	YES/NO/EVER____________________
emphysema	YES/NO/EVER____________________
tuberculosis	YES/NO/EVER____________________
chronic cough	YES/NO/EVER____________________
other__________	YES/NO/EVER____________________

5.Are you short of breath when you are	sitting	YES/NO
	walking	YES/NO
	eating/drinking	YES/NO
	finished eating/drinking	YES/NO
6.Do you cough frequently?		YES/NO

7.Is the coughing associated with anything?____________________

8.Are you on home oxygen? YES/NO

HEAD AND NECK MEDICAL HISTORY

9.Have you had surgery to your head, neck or mouth? YES/NO

What type of surgery did you have? ____________________

When did you have the surgery? ____________________

10.Have you had radiation to your head, neck or mouth?(Please circle area)YES/NO

NEUROLOGICAL MEDICAL HISTORY

11.Have you had a stroke or CVA? YES/NO

12.Do you have a degenerative neurogical disease?
(eg MS, parkinsons, MND) YES/NO

13.Do you have any other neurological disease/disorder? YES/NO

OTHER RELEVANT MEDICAL HISTORY

CURRENT MEDICATIONS

(eg zantac, tagamet)

SWALLOWING HISTORY

14.Have you had any recent weight loss? YES/NO

15.Time over which weight loss has occurred_____________month/s

16.How much weight was lost______________kg

17.Do you have any difficulty swallowing? YES/NO

18.How long have you had these difficulties? __________________month/s

19.What type of food do you eat at home?(Please circle)

Normal diet Soft foods Blended foods

20.Do you have difficulty eating or drinking any of the following?(Please circle)

Steak dry biscuits cereal bread salads nuts

corn vegetable soupwater tea coffee soft drink

Other ____

21.Do you have to chew your food extremely well? YES/NO

22.Do you cut your food into small pieces? YES/NO

23.Do you eat (Please circle) QUICKLY AT A STEADY PACE SLOWLY

24.Do you drink (Please circle) QUICKLY AT A STEADY PACE SLOWLY

25.Do you cough when drinking (Please circle)

every time you drink once a day once a week

once a month less than once a month

26.Do you cough when eating (Please circle)

every time you eat once a day once a week

once a month less than once a month

27.Do you choke when drinking (Please circle)

every time you drink once a day once a week

once a month less than once a month

28.Do you choke when eating (Please circle)

every time you eat | once a day | once a week

once a month | less than once a month

29.Do you have difficulty swallowing tablets? YES/NO

30.Does food or drink ever go up your nose? YES/NO

31.How often does this occur?

every time you eat/drink | once a day | once a week

once a month | less than once a month

32. Do you clear your throat when you eat or drink? YES/NO

APPENDIX D

SCALES OF PERCEIVED DYSPNOEA (SHORTNESS OF BREATH)

PART ONE

PLEASE CIRCLE LEVEL OF SHORTNESS OF BREATH

0 EQUALS NO SHORTNESS OF BREATH AND 10 EQUALS THE MOST SHORT OF BREATH YOU COULD BE

0 1 2 3 4 5 6 7 8 9 10

PART TWO

PLEASE CIRCLE LEVEL OF SHORTNESS OF BREATH

0 EQUALS NO SHORTNESS OF BREATH AND 10 EQUALS THE MOST SHORT OF BREATH YOU COULD BE

0 1 2 3 4 5 6 7 8 9 10

APPENDIX E

SPEECH PATHOLOGY SWALLOWING ASSESSMENT

Patient's Name: ____________________

Address: ____________________

Phone: ____________________

Medical Record No. ____________________

Languages spoken: ____________________

Assessment Date: ____________________

Aetiology: ____________________

Diabetes:	IDDM	NIDDM	Non Diabetic
Chest Condition:	Reg. Suctioning	Basal creps	Good
Chest X-ray:	Date: __________	Results: __________	
Alertness:	Unconscious	Fluctuating Level of Alertness	Alert
Dentition:	Full Denture	Partial Denture	Ill Fitting Denture
	Full Own Dentition	Partial Own Dentition	
Comprehension:	Able to follow commands	Unable to follow commands	
Mental Status:	Confused	Orientated	
Posture:	Able to be seated	Unable to be seated	

Comments:

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AIRWAY PROTECTION MECHANISMS

Voluntary cough:	Weak	Adequate		Strong
Reflexive Cough:	Weak	Adequate		Strong
Vocalisation:	Aphonic	Weak	Hoarse Strong	
Throat Clear:	Effective		Not Effective	

OROMUSCULATURE ASSESSMENT

Cranial Nerve	Test Proceedure	Normal/Impaired
Trigeminal	-Palpatation of masseter -Closing and lateralisation against resistance	
Facial	-Observation of symmetry at rest -Wrinkle forehead -Close eyes tightly -Smile -Pucker -Pull down lip corners	
Glossopharyngeal	-Must be tested with C.N. X	
Vagus	-Observation of palatal movement -Gag reflex -Evaluation of vocal quality -Ability to change pitch and phonation time	
Hypoglossal	-Observations for atrophy or fasiculations -Symmetry on protrusion -Lateralisation -Protrusion -Elevation -Retraction Against resistance: -Lateralisation -Protrusion -Elevation	

FOOD TOLERANCE

CURRENT FEEDING METHOD

1. IV only		5. IV + Oral	
2. TPN		6. NG + Oral	
3. NG tube		7. PEG + Oral	
4. PEG		8. Oral only	

FOOD TOLERANCE

Thin Liquid	L	Sandwich	R
Thin Thick Liquid	T	Biscuit	B
Thickened Liquid	K	Capsule	C
Puree	P	Marshmallow	M
Pear piece	S	Tablet	Ta

Specify level of difficulty: 1=normal 2=Minimal 3=Moderate 4=Severe

ORAL PHASE

1. Spillage from lips		3. Tongue Pumping	
2. Inability to form bolus		4. Unable to clear mouth	

PHARYNGEAL PHASE

1. Delayed initiation of swallow		6. Coughing During Swallow	
2. Multiple swallows to clear bolus		7. Coughing After Swallow	
3. Unable to initiate swallow		8. Instructed Cough	
4. 'Gurgly' phonation following swallow		9. Decreased Laryngeal Elevation	
5. Coughing Before Swallow		10. O2 Desaturation - below 95% (NB: O2/Room Air)	

USEFUL THERAPEUTIC MANOEUVRES

1. Neck Flexion	
2. L R Head Rotation	
3. L R Head Tilt	
4. Small Bolus	
5. Large Bolus	
6. Straw	
7. Spoon	
8. Supraglottic Swallow	

ASSOCIATED SYMPTOMS

Pain	
Nasal Regurgitation	
Obstruction	
Altered Sensation	
Aspiration	

RECOMMENDED DIET REGIME

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PRECAUTIONS TO BE OBSERVED

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APPENDIX F

MODIFIED BARIUM SWALLOW - CAL RESEARCH FORM

PATIENT: .... CAL / NORMAL PRE-STRESS / POST-STRESS

FILE NO: .... DOB: ..../..../.... AGE:........

VIDEO: ....

Consistencies: D= 50/50 (sips) P= Puree L= Liquid Barium F= Pear and syrup B= Biscuit
S= Sandwich C= Capsule T=Tablet A= All H= Continuous drinking 50/50 (100mls)

Level of Difficulty: 1= Normal / Effective 2= Minimal 3=Moderate 4= Severe 5= Present / Absent feature

Factors affecting swallow: 6= Fatigue 7= SOB 8= Intermittent 9= Brief/transient

ANATOMIC	ORAL PHASE PREPARATORY	ORAL PHASE PROPER
1A. Oral scarring	2A. Lip seal	3A. Forward tongue thrust
1B. Pharyngeal scarring	2B. Oral phase (onset)	3B. Oral residue
1C. Zenker's Diverticulum	2C. Bolus formation	3C. Tongue pumping
1D. Osteophytes	2D. Bolus control	3D. Piecemeal deglutition
1E. Tracheo-oesophageal fistula	2E. Chewing	3E. Oral transit
1F. Web		3F. Lingual / palatal contact
1G. Tumour		
PHARYNGEAL PHASE	**PHARYNGEAL PHASE (Cont.)**	**OESOPHAGEAL PHASE**
4A. Onset of pharyngeal phase	4N. Aspiration after swallow	5A. Oesophageal peristalsis
4B. Palatal closure	4O. Silent Aspiration	5B. Tertiary oesophageal waves
4C. Nasal regurgitation	4P. Laryngeal elevation	5C. Oesophageal spasm
4D. Hypopharyngeal residue	4Q. Opening UES	5D. Oesophageal stricture
4E. Vallecular residue	4R. Cricopharyngeal bar	5E. Achalasia
4F. Post. Pharyngeal wall residue	4S. Epiglottic movement	5F. Motility disorder
4G. Pyriform sinus residue	4T. Hyoid movement	5G. Hiatus hernia
4H. Pharyngeal peristalsis		5H. Gastro - oesophageal reflux
4I. Asymmetrical bolus flow	**LARYNGEAL PROTECTION**	
4J. Laryngeal penetration	4U. Spontaneous cough	**Other features:**
4K. Inhalation	4V. Instructed cough	....
4L. Aspiration before swallow		....
4M. Aspiration during swallow		....

CONSISTENCY	**ORAL TRANSIT TIME (SEC)**	**PHARYNGEAL TRANSIT TIME (SEC)**	**NO. SWALLOWS**	**TOTAL TRANSIT TIME (SEC)**
50/50 sips (1)				
50/50 sips (2)				
100mls continuous				
Pear and syrup (1)				
Pear and syrup (2)				
Biscuit				
Sandwich				
Capsule				

Comments:

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Adapted from the Modified Barium Swallow Date Base, Mendelsohn (1994) by Kaatzke - McDonald, Reid (1997).

APPENDIX G

DEFINITIONS FOR THE MODIFIED BARIUM SWALLOW

Adapted from: A students guide to dysphagia management.
Videofluoroscopy interpretation, M. Kaatzke - McDonald (1997) by K. Reid (1997)
Key: 1=normal, 2=mild, 3=moderate, 4=severe, 5=present/absent, 6=silent aspiration

FEATURE	OBSERVATIONS	MINIMAL	MODERATE	SEVERE
2A. Lip seal	*Incomplete lip closure *Difficulty / inability to remove food from spoon *Leakage of bolus out of the mouth *Affects ability to form a cohesive bolus	Leakage of <10% bolus	Leakage of 10 -50% bolus	Leakage of >50% bolus
2B. Oral phase (onset)	Commencement of mastication of the bolus and / or bolus formation	Commences up to 1 second	Commences up to 2 seconds	Commences after 2 seconds
2C. Bolus formation	*Ability to form a cohesive bolus which can be seen held in the oral cavity *Bolus spreads through mouth	Difficulty forming bolus	Partial bolus formation	Unable to form bolus
2D. Bolus control	*Inability to hold food/fluid in a cohesive bolus *Material spreads through the oral cavity	Loss of control of up to 10% of bolus	Loss of control of up to 50% of bolus	Loss of control of >50% of bolus
2E. Chewing	*Inadequate / inefficient mastication *Unable to align teeth *Unable to lateralize food/fluid	Slow to masticate food but able to get a sufficiently fine texture	Incomplete mastication of the bolus. Larger	Unable to masticate bolus

		to form a bolus	particles still apparent	
3A. Forward tongue thrust	Present / absent			
3B. Oral residue	*Residue of food/fluid on the palate, tongue or in the lateral sulcus	Less than <10% bolus remaining in oral cavity	10 -50 % of the bolus remaining in oral cavity	>50 % of the bolus remaining in oral cavity
3C. Tongue pumping	Present / absent			
3D. Piecemeal deglutition	*Division of the bolus into smaller quantities to swallow	Fluids - 2 swallows Solids - 3 swallows	Fluids - 3 to 4 swallows Solids - 4 to 5 swallows	Fluids - > 4 swallows Solids - > 5 swallows
3E. Oral transit	*Normal duration < 1 second *Disorganised or slow anterior - posterior bolus movement	Duration of 1 - 2 seconds	Duration of 2 - 3 seconds	Duration of >3 seconds
3F. Lingual / palatal contact	*Tongue touches the palate on posterior propulsion of the bolus Present / absent			
4A. Onset of pharyngeal phase	*The pharyngeal phase should be triggered in young people as the head of the bolus reaches the anterior faucial arches, in older adults (60+), as the bolus head reaches the region where the lower edge of the mandible crosses the base of the tongue	Between the lower edge of the mandible and the valleculae	In the valleculae	In the pyriform sinuses
4B. Palatal closure	*The soft palate is approximating the posterior pharyngeal wall Present / absent			

4C. Nasal regurgitation	*Food / fluid enters the nasal cavity Present / absent			
4D. Hypo pharyngeal residue	*Residue of food / fluid in the hypopharynx Present / absent			
4E. Valleculae residue	*Residue of food / fluid in the valleculae	Coating	Up to ½ full	Full
4F. Post pharyngeal wall residue	*Residue of food / fluid on the post pharyngeal wall Present / absent			
4G. pyriform sinus residue	*Residue of food / fluid in the pyriform sinuses	Coating	Up to ½ full	Full
4H. Pharyngeal peristalsis	Present / absent			
4I. Asymmetrical bolus flow	Present / absent			
4J. Laryngeal penetration	Food/fluid enters the laryngeal vestibule but does not pass the vocal cords	Penetration is transient (<1 second) and above the level of the cords	Penetration is transient (<1 second) and to the level of the cords	Penetration is to the level of the cords
4K. Inhalation	Present / absent			
4L. Aspiration before swallow	Food/fluid passes through and below the vocal cords. Occurs prior to eliciting the swallow. Present / absent			

4M. Aspiration during swallow	Food/fluid passes through and below the vocal cords. Occurs while the swallow is in progress. Present / absent			
4N. Aspiration after swallow	Food/fluid passes through and below the vocal cords. Occurs after the swallow is complete. Present / absent			
4O. Silent aspiration	Food/fluid passes through and below the vocal cords. No spontaneous cough is elicited. Present / absent			
4P. Laryngeal elevation	Present / absent		Partial	
4Q. Opening UES	Present / absent			
4R. Cricopharyngeal bar	Present / absent			
4S. Epiglottic movement	Present / absent		Incomplete	
4T. Hyoid movement	Present / absent			
4U. Spontaneous cough	Stimulated after aspiration / laryngeal penetration Present / absent			
4V. Instructed cough	Used when no cough is stimulated after aspiration or spontaneous cough is ineffective Present / absent			