AN INVESTIGATION OF THE EFFECTS OF NASOGASTRIC TUBES ON THE YOUNG, NORMAL SWALLOWING MECHANISM

by

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DECLARATION

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ABSTRACT

AN INVESTIGATION OF THE EFFECTS OF NASOGASTRIC TUBES ON SWALLOWING IN YOUNG, NORMAL ADULTS

by

PHILLIPA SARAH CLARKSON

This study investigated the effects of nasogastric tubes on swallowing in 10 young, normal adults, utilizing videofluoroscopy. The relationship between nasogastric tube size and swallowing was also examined.

Each subject was required to swallow 2 x 5 ml amounts of barium under three different experimental conditions i.e. 'tube-out'; fine-bore nasogastric tube in situ; and wide-bore nasogastric tube in situ. A total of sixty swallows were obtained for the ten subjects. Five durational measures of bolus movement and specific swallowing events were obtained. These were: Duration of Velar Elevation (DOVE), Duration of Stage Transition (DST), Duration of Pharyngeal Response (DPR), Duration of Pharyngeal Transit (DPT) and Duration of Upper Oesophageal Sphincter Opening (DUOSO). In addition, three non-temporal swallowing measures i.e. adequacy of bolus containment, adequacy of pharyngeal bolus clearance, and adequacy of airway protection were obtained. Statistical analysis of the data employed One-Way Analysis of Variance measures, and Multiple Range Analyses using the test of Least Significant Difference.

The major finding of this investigation was that wide-bore nasogastric tubes significantly increased the values of three of the five durational measures (DPR, DPT and DUOSO) in comparison to the 'tube-out' condition. Although some slowing of the durational measures was seen for the fine-bore nasogastric tube condition, these changes were statistically significant only for the DUOSO measure. The findings indicate that wide-bore nasogastric tubes significantly interfered with the efficacy of young, normal swallowing mechanisms. Nasogastric tubes did not cause any significant changes in the three non-temporal swallowing parameters, suggesting that the function of young, normal swallowing mechanisms is not affected by nasogastric tubes.

The findings of this study have clinical implications for dysphagia management, specifically the selection of non-oral feeding methods. Fine-bore rather than wide-bore nasogastric tubes are recommended for nasogastric tube feeding.

PREFACE

This study represents original work by the author and has not been submitted in any form to another University. Where use was made of the work of others it has been duly acknowledged in the text.

The research described in this dissertation was carried out in the Department of Logopaedics, University of Cape Town, under the supervision of Associate Professor Seppo Tuomi (Logopaedics) and Dr Christopher Young (Radiology).

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CHAPTER 1
INTRODUCTION

Swallowing is a complex neuromuscular sequence involving a variety of integrated, interdependent patterns of motor activities that occur simultaneously and rapidly in a predetermined order (Sonies, 1991). These behaviours are governed by cranial nerves in the brainstem, and neuro-regulatory mechanisms in the medulla, sensori-motor and limbic cortical systems (Bass and Morrell, 1992).

Swallowing normally occurs as an orderly physiologic process that transports ingested material and saliva from the mouth to the stomach (Dodds et al., 1990). This process occurs smoothly and easily in three well-defined phases, namely, the oral phase, the pharyngeal phase and the oesophageal phase (Donner et al., 1985; Logemann, 1983). As Diamant (1995) eloquently notes, " the functional elegance of the system is matched only by the serious medical and social consequences of its failure: malnutrition, pulmonary complications and loss of personal and social pleasures that accompany eating."(p.1700).

Difficulty with swallowing, or dysphagia, may interfere with any of the three phases of deglutition. It may be classified as oropharyngeal or oesophageal dysphagia (Donner et al., 1985). Dysphagia can be caused by a number of structural or motor disorders (Cook, 1991; Logemann, 1991). Structural disorders result from surgery, the sequels of radiotherapy, tumours, strictures and extrinsic compression of the pharynx or oesophagus. Motor disorders are caused by muscle involvement or a neurogenic impairment of the sensory or motor nerves innervating the region (Cook, 1991).

The number of swallowing disordered persons in the neurogenic population appears to be substantial, and is particularly prevalent in the elderly (Finucaine et al., 1991). Cerebrovascular accidents seem to be the most common basis for neurogenic dysphagia (Bucholz, 1994). Reports differ as to the exact incidence, but approximately 45% of stroke patients suffer from dysphagia (Horner and Massey, 1988; Linden and Siebens, 1983). Those with multiple infarcts, pseudobulbar palsy and brainstem damage are most at risk for prolonged swallowing problems (Allison et al., 1992). Neurogenic dysphagia is also frequently related to degenerative neurological diseases, head injuries and post-operative complications (Logemann, 1983; Ott and Pikna, 1993).

Dysphagia is a serious problem with potentially fatal consequences (Barer, 1989). Certainly, in acute stroke, dysphagia is associated with increased mortality (Allison et al., 1992). Gordon (1987, in Norton et al., 1996) demonstrated a 50% mortality at six weeks among dysphagic monohemispheric stroke patients. Complications of dysphagia include dehydration, nutritional compromise (Norton et al., 1996; Sitzman, 1990) and aspiration (Horner and Massey, 1988; Langmore, 1991). Of all the problems that occur as a result of dysphagia, aspiration and the development of aspiration pneumonia, are clinically the most significant (Langmore, 1991). Dysphagia is the primary cause of aspiration (Langmore, 1991). Aspiration pneumonia is the fifth leading overall cause of death in the United States, and the fourth most common cause of death in the elderly (Langmore, 1991). Aspiration and the development of aspiration pneumonia may also have a major impact on health costs, as a patient with aspiration pneumonia will have a significantly longer stay in an acute-care facility (Young et al.,1980).

In order to minimize the risks of dysphagia, alternative non-oral methods of feeding are usually considered. A number of non-oral feeding options are currently available. These include nasoenteric routes (nasogastric, nasoduodenal and nasojejunal) and gastrostomy (surgical or percutaneous endoscopic) (Kirby et al., 1995). Nasogastric tube feeding is the most widely utilized non-oral feeding method (Finucaine et al., 1991). Tube feeding has been practised in some form since Roman times (Grossman et al,. 1984). In the 12th century A.D., Aven Zoar, a Cordovan physician-surgeon and pharmacist suggested that a silver or tin tube be pushed down the oesophagus into the stomach for feeding purposes (Leonardo, 1943 in Grossman et al., 1984). This was duly attempted in Padua in the 1500's, where the first nasogastric tube, a silver cannula for forced feeding through the nose, was described (Leonardo, 1943 in Grossman et al., 1984). The first documentation of a flexible feeding tube was by John Hunter in 1790 (Mettler and Mettler, 1947 in Sofferman and Hubbel, 1981). He described the use of a fresh eel skin stretched over a whalebone, and introduced into the stomach for feeding a patient with paralysis of the swallowing mechanism.

It was only in 1874 that soft pliable rubber stomach tubes were developed. In the 19th century, the use of nasogastric tubes focused on lavaging the stomach in cases of opium poisoning (Grossman et al., 1984). In 1921, Levin described the tube which still bears his name (Levin, 1921, in Grossman et al., 1984). The tube was made of rubber with a velvet eye at the tip. He recommended that this tube be passed by the nasal route (Grossman et al., 1984). Since then a number of tubes of different materials have been developed (Grossman et al.,1984). Traditionally, wide-bore tubes (such as Ryle's French Gauge 16) were used to deliver enteral feeds to the stomach (Bastow, 1986).

The traditionally used wide-bore tubes are no longer recommended for feeding purposes as they are made of stiff polyvinylchloride which is uncomfortable for the patient (Deel-Smith and Symmonds, 1989). They are also associated with a high prevalence of oesophagitis, oesophageal ulceration and cardiac sphincter incompetence (Deel-Smith and Symmonds, 1989). Recent technical innovations have led to greatly improved tubes, both in terms of efficiency and patient comfort (Deel-Smith and Symmonds, 1989). The introduction of soft, flexible fine-bore tubes (French Gauge 5-8) has significantly minimized the problems associated with wide-bore tubes (Bastow, 1986; O'Keefe, 1993).

Despite the obvious advantages of fine-bore tubes, many patients continue to receive feeds via wide-bore tubes (Bastow, 1986). As wide-bore nasogastric tubes are fairly rigid, they are less likely to coil up or become displaced during insertion. Consequently, they are easier to insert than fine-bore nasogastric tubes. Furthermore, radiology may be required to confirm correct siting of fine-bore tubes, thereby exposing patients to unnecessary radiation (Bastow, 1986). Thus the continued use of wide-bore tubes may be encouraged in patients who require repeated intubation, particularly the elderly and stroke patients (Finucaine et al. 1991). Rees et al. (1989, cited in Park et al., 1992) noted that as many as 23% of nasogastric tubes were removed unintentionally within 24 hours of initiating non-oral feeds. Reintubation is both distressing for the patient, as well as time-consuming for medical and nursing staff (Park et al., 1992).

Both wide and fine-bore nasogastric tubes are associated with a number of complications. Sitzman (1990) reports a 40% complication rate related to nasogastric tube feeding. General complications include mechanical or tube-related problems such as clogging; tube misplacement or dislodgement; and nasopharyngeal trauma and ulceration (Kirby et al., 1995). Gastrointestinal complaints include gastroesophageal reflux; oesophageal, gastric and duodenal erosions and perforations (Kirby et al., 1995; Jones, 1986).

Pulmonary complications such as aspiration pneumonia (Fay et al., 1991) and tracheobronchial intubation (Grossman et al.,1984) are more debilitating problems associated with nasogastric feeding. This seems paradoxical as one of the aims of non-oral feeding is the prevention of any pulmonary problems. Fay et al. (1991) and Allison et al. (1992), suggest that the presence of a tube traversing the upper and lower oesophageal sphincters is believed to disrupt the normal cough and swallow mechanisms and increase the risk of gastroesophageal reflux and aspiration. Grossman et al. (1984) also note that while fine-bore tubes are more comfortable for the patient, their flexibility makes them prone to disastrous undetected misplacement into the trachea. Sitzman (1990) reports that patients with neurogenic dysphagia, who most commonly receive nasogastric feeding, were found to have nearly a two-fold increase in complications associated with nasogastric tubes. Furthermore, nasoenteric feeding was associated with a 35% mortality rate. This mortality rate was significantly higher than that associated with other feeding modalities, such as gastrostomy. Similar observations were made by Norton et al. (1996).

Aside from the general complications of nasoenteral feeding reported in the literature, a number of reports illustrate specific injuries and complications of nasogastric tubes. Sofferman and Hubbel (1981) document four cases of bilateral vocal cord paralysis associated with the use of nasogastric tubes. They went on to carry out a prospective study of the effects of nasogastric tubes on the normal human larynx. In a group of 57 nasogastrically intubated patients, arytenoid oedema developed in approximately one third of the subjects. Friedman et al. (1981) report the development of cricoid chondritis secondary to midline nasogastric intubation in three patients. They noted that if left untreated, cricoid chondritis may progress to cartilage necrosis and subglottic stenosis, occasionally necessitating tracheotomy (Friedman et al., 1981).

Both the pharynx and the oesophagus are particularly susceptible to trauma during nasogastric tube insertion, and as a result of continuous local irritation by indwelling tubes (Gharemani et al., 1980). Wolff and Kessler (1973) investigated iatrogenic injury to the hypopharynx and cervical oesophagus, and found that 60% of all adults studied in a series of consecutive autopsies, had some form of oral or nasal intubation performed, either using endoscopes or flexible nasogastric tubes. Injury to the hypopharynx and oesophagus was noted in 60% of these patients. Relatively short-term nasogastric tube use (five days) was associated with the development of post-cricoid ulcers.

For many of these reasons, patients requiring long-term non-oral feeding (more than 30 days) are often considered for alternatives to the nasoenteric routes (Kirby et al., 1995). An increasingly popular alternative to nasogastric tube feeding is feeding via Percutaneous Endoscopic Gastrostomy (PEG) (Kirby et al., 1995; Moran and Frost, 1992; Park et al, 1992). PEGs were developed as an alternative to surgically created gastrostomy, thus avoiding an operative procedure under general anaesthesia (Forgas et al., 1992).

Another advantage, is that PEG feeding may improve the outcome of rehabilitation following stroke. Allison et al.(1992) found that PEG feeding initiated four to six months following the onset of the stroke, was associated with nutritional improvement, marked functional recovery and eventual discharge from hospital. There is also some indication that patients fed via PEG recover speech and swallowing faster than those fed via nasogastric tubes (Davis, 1994; Moran and Frost, 1992;).

It is possible that by interfering with various aspects of swallowing, a nasogastric tube interferes with swallowing recovery. Davis's (1994) observation that a nasogastric tube may interfere with swallowing, even in patients who have normal swallowing mechanisms, supports this hypothesis. Davis (1994) suggests that the presence of a nasogastric tube in the nasopharynx irritates the mucosa and hampers soft palate elevation. In addition to hindering swallowing, resonatory patterns may be impaired due to compromised velopharyngeal closure. Constant pressure of the tube on the soft palate over a long time period may also have an adverse effect on subsequent functional recovery, both of speech and swallowing.

The presence of the tube in the nasal passage may also interfere with normal breathing patterns. Breathing with a tube in the nose, or breathing through the mouth, were rated by Padilla et al. (1979) as psychosensory irritations associated with nasogastric tube feeding. Mouth breathing often dries out the buccal mucous membranes. The conditions of a moist buccal cavity, open nostrils and a closed mouth, are necessary for normal swallowing patterns (Bass and Morrell, 1992), and are clearly violated by the presence of a nasogastric feeding tube.

Disturbed sensory feedback in the pharynx may occur due to the anaesthetic effect caused by long-term accommodation of the nasogastric tube (Davis, 1994). Mechanical interference by the tube on hyolaryngeal movement may lengthen the pharyngeal response time of the swallow, and generally lengthen the overall transit time of the pharyngeal bolus.

Despite the fact that there is considerable clinical awareness both of the complications associated with nasogastric tubes, and the negative influence of nasogastric tubes on swallowing (Davis, 1994; Padilla et al., 1979), the literature contains very little objective information on the effects of nasogastric tubes on the physiology of the swallowing mechanism. Kidder et al. (1994) investigated flexible nasal endoscopy as a technique to evaluate swallowing function. They advocate caution when comparing the swallowing behaviours observed during flexible nasal endoscopy with the individual's normal swallowing patterns. It is possible that the presence of an endoscopic tube inserted transnasally, may alter swallowing physiology. They go on to note that the influence of the nasoendoscopic tube on swallowing has yet to be adequately studied. As the technique of transnasal passage of a tube into the pharynx, applies both to flexible nasal endoscopy as well as to nasogastric intubation, these observations and cautions may also apply for nasogastric tubes.

In possibly the most relevant literature on the effects of a tube on swallowing physiology, Robbins et al. (1992) examined swallowing in normal adults of different ages. Manometry was incorporated into the study to investigate pharyngeal pressures and contractions. The presence of the manometric tube in the nasopharynx, pharynx and cervical oesophagus was noted to create significant durational changes in normal swallowing patterns. The duration of velar elevation was found to be significantly **shorter** for the 'tube-in' condition than for the 'tube out' condition. This finding correlates well with Davis' (1994) observation that the presence of a nasogastric tube hampers soft palate elevation. The most likely explanation for this observation, is that the tube prevents adequate contact between the velum and posterior pharyngeal wall, leading to shortening of the overall velar elevation time.

Other temporal swallowing measures in Robbins et al.s' (1992) study were found to be significantly **longer** for the 'tube-in' condition. In particular, the durations of hyoid maximal elevation, hyoid maximal anterior excursion and upper oesophageal opening were all significantly **longer** for the 'tube-in' condition as opposed to the 'tube-out' condition. It seems likely that these durational changes were the result of the mechanical effect of the manometric tube inhibiting movement in various pharyngeal structures.

Robbins et al. (1992) also noted that in the oldest age group (> 70 years old), the pharyngeal response duration was significantly **longer** for the 'tube-in' condition than for the 'tube-out' condition. This was not seen in the younger age groups, and suggests an age-related change in the ability to compensate for the presence of a tube. Furthermore, the manometric 'tube-in' condition was associated with a greatly increased frequency of laryngeal penetration in the oldest age group. Robbins et al. (1992) associated this prolonged laryngeal vestibule opening with the increased pharyngeal response duration.

Robbins et al.s' (1992) finding of more frequent laryngeal penetration in the older age group, has important clinical implications when considering that dysphagia is prevalent in the elderly hospitalized patient (Finucaine et al., 1991), who is usually fed nasogastrically. If the presence of a tube leads to an increase in vestibular opening and an increased incidence of penetration in **normal** elderly individuals, what effect does a tube have on dysphagic patients?

It is well-known that nasogastric tubes may increase the risk of aspiration because of gastroesophageal reflux. Mittal et al. (1992, in Kirby et al., 1995) note that a tube passed through the pharynx may lead to more transient relaxations of the lower oesophageal sphincter, and this may promote gastroesophageal reflux. However, Robbins et al.s' (1992) observations above, suggest that the tube may also lead to **oropharyngeal** aspiration because of the prolonged vestibular opening.

A number of interesting questions arise out of the Robbins et al. (1992) study. Firstly, the primary aim of their investigation was to examine swallowing in normal adults of different ages. The effects of the manometric tube on swallowing were essentially secondary. Little attention was paid to the physical characteristics of the manometric tube. Factors such as tube flexibility and circumference were not adequately described. Robbins et al. (1992) note that the "relatively large size of the combined catheters" (p. 828) needs to be considered when interpreting the test results, but they fail to specify the catheter dimensions, particularly the tube circumference.

Due to these unknown factors in Robbins et al.s' (1992) methodology, conclusions cannot be drawn about the effects of **nasogastric tubes** on swallowing physiology. In addition, Robbins et al. (1992) utilized only one manometric tube of unspecified circumference. The literature suggests that fine-bore tubes which have a small circumference, are subjectively more comfortable than wide-bore tubes (Deel-Smith and Symmonds, 1989; Padilla et al., 1979). It seems plausible, that fine-bore tubes would have a less negative effect on swallowing physiology than wide-bore tubes. This, however, needs to be objectively investigated by comparing the effects of fine and wide-bore nasogastric tubes on swallowing function.

Robbins et al. (1992) found a number of significant durational changes associated with the presence of a tube. Unfortunately they did not investigate whether or not a tube interferes with the triggering of a pharyngeal swallowing response. Delayed triggering of the pharyngeal swallowing resopnse is frequently associated with aspiration in dysphagic patients (Logemann,1986; Logemann,1988, in Robbins et al., 1992). A nasogastric tube may possibly delay triggering of a swallowing response, and thus predispose to aspiration in persons with dysphagia. This would have significant implications for clinical practice.

Additionally, the pharyngeal transit time, that is, the time the bolus takes to move through the pharynx, was not noted in Robbins et al.s'(1992) study. A tube might interfere with the passage of a bolus, thereby lengthening the total pharyngeal transit time. Although this is not clinically as significant as aspiration, it may negatively impact upon swallowing recovery and rehabilitation, by increasing the total swallowing time in a patient who may fatigue easily.

In summary, Robbins et al.s' (1992) study is an important study relating the potential effects of a tube in the pharynx on swallowing. They demonstrate that the presence of a manometric tube causes significant durational changes in normal swallowing patterns. One of the weaknesses of the study is that the manometric tube circumference is not specified, making it difficult to replicate their methodology. Furthermore, only one manometric tube of inadequately specified dimensions, was utilized in their study. Therefore, observations on the effects of **different** size tubes on swallowing physiology cannot be made.

The aim of the present study was to objectively address the effects of **nasogastric tubes** on normal swallowing physiology. In addition, the differential effects of fine and wide-bore nasogastric tubes on swallowing function, were targeted for investigation. Only young, normal subjects were studied, to eliminate age-related swallowing changes (Robbins et al., 1992). The method of videofluoroscopy was used to determine the relationship between different size nasogastric tubes on the temporal parameters of normal oropharyngeal swallowing movements and bolus transit motion. Each subject served as their own control, allowing comparison of the individual's normal swallowing patterns with their swallowing in the presence of a nasogastric tube.

CHAPTER 2
METHODOLOGY

This study was approved by the Research Ethics Committee of the University of Cape Town's Faculty of Medicine.

2.1 Aims

The aims of this study were:

1) to determine whether the presence of a nasogastric tube in the nasal and pharyngeal cavities causes significant durational changes in the bolus movement and specific events within the swallowing of young, normal adults.

2) to determine whether nasogastric tube size influences swallowing efficacy.

3) to determine whether the following non-temporal parameters of swallowing: bolus containment; efficacy of pharyngeal bolus clearance; and adequacy of airway protection, are influenced by the presence of a nasogastric tube.

2.2 Subjects

2.2.1 Subject Selection Criteria

2.2.1.1 Age

All subjects were required to be between the ages of 18 to 45 years of age. As age-related changes interfere with normal swallowing patterns, only young normal adults were considered as subjects. Robbins et al. (1992) note that swallowing begins gradually slowing sometime after 45 years of age. At approximately 70 years, swallowing is significantly slower than in individuals younger than 45. In the present study, the mean age of the ten subjects was 22,7 years, with a range from 20 to 27 years.

2.2.1.2 Sample size

Ten young adults (7 female, 3 male) served as subjects. Robbins et al. (1992) suggested that an ideal sample size of a group for a study of this nature, was 20 subjects (10 males/10 females). However, as the present study was a pilot study, and differences were anticipated between experimental conditions, on the basis of previous research (Ventry and Schiavetti, 1980), a sample size of 10 subjects was felt to be acceptable for this investigation. Furthermore, the study was a within-subjects design, using repeated measurements, which permits small sample sizes (Ventry and Schiavetti, 1980).

2.2.1.3 Sex

Both male and female volunteers were sought as subjects, to allow for an analysis of possible gender differences between male and female swallowing patterns. Equal male/female ratios were considered the ideal although 7 females and 3 males participated in the present study.

2.2.1.4 Speech and Swallowing Characteristics

A history of any oral-motor or speech dysfunction, or swallowing dysfunction (developmental, neurological or structural) , excluded subjects from participating in this study. All subjects were required to perform normally on a standard oropharyngeal sensorimotor examination. Specific exclusion criteria were abnormalities of lip closure, tongue strength and mobilty, velar elevation and laryngeal functioning. Surgery to the head or neck, or a history of medical conditions affecting head, neck or digestive structures, prevented subject participation. Use of medications that could interfere with the normal functioning of the swallowing mechanism was another exclusion criterion.

2.2.2 Subject Selection Procedure

University of Cape Town students were approached by the researcher, and requested to volunteer as subjects in the study. Each potential participant was informed verbally and through a Subject Information Sheet (See Appendix A) of the nature of the study. Each participant was required to sign a Consent Form (See Appendix B), and undergo a standard oropharyngeal sensorimotor examination. 12 normal volunteers (9 females and 3 males) were originally recruited as subjects. Two subjects were later eliminated from the study, as nasogastric tube intubation could not be succesfully performed on them. This left 10 subjects (7 females and 3 males) to participate in the study.

2.3. Data collection

2.3.1 Equipment

The radiographic and fluoroscopic unit consisted of a Shimadzu Photo Timer image intensifier, and a closed circuit television. Fluoroscopic examinations were performed in the Radiology Department of Groote Schuur Hospital, in a radiologic screening suite. The Radiographic and Fluoroscopic unit was kept at a screening setting of 30 MA, 75 Kv. Subjects were exposed to a fluoroscopy dosage equivalent to 336 milliroentgens, for a maximum exposure period of 15 minutes. This is in accordance with World Health Organization regulations stipulating fluoroscopic exposure for the 'standard man' (Dr M. Shackleton - Personnal communication).

The fluoroscopic television image was recorded directly onto one-inch high quality videotape, by a Panasonic AG 6200 Videorecorder. The built-in edit control of this videorecorder, allowed for slow-motion; frame-by-frame analysis; stopping frames; and forward and rewind options. This facility was used in later temporal slow motion and frame-by-frame analysis of the swallow motion and bolus transit times.

2.3.2 Procedure

All videofluoroscopic swallow studies were recorded in the standard erect, lateral position (Golding, 1991). The subject's head faced forwards in a neutral position. Appropriate collimation was used to frame a lateral image of the posterior oral cavity, pharynx and cervical oesophagus, as described by Shaker et al. (1994). Each swallow was recorded progressing from normal shallow breathing, through a solitary swallow, to quiet breathing again, as described by Curtis et al. (1984). Approximately 10 to 15 seconds of fluoroscopy was utilized for each swallow view.

Each subject was required to swallow two 5ml amounts of undilute barium sulphate (EZ Paque - Protea Medical Laboratories) under three different experimental conditions:

1) condition 1 - 'tube-out' (no nasogastric tube)

2) condition 2 - fine-bore nasogastric tube in situ
   (French Gauge 8 x 85 cm length - Ven Medical Products)

3) condition 3 - wide-bore nasogastric tube in situ
   (Levins Tube French Gauge 16 x 122 cm length - Ven Medical Products)

The 'tube-out' condition was always first in the experimental sequence, followed by the two 'tube-in' conditions. The order of these two 'tube-in' conditions was decided randomly. Intubation was conducted under radiological guidance by a consultant radiologist. The tubes were lubricated with a non-anaesthetic jelly, and inserted transnasally into the oesophagus. The liquid barium was placed in the mouth with a 5ml syringe. Subjects were instructed to hold the barium in their mouth, until they were told to swallow it as a single bolus.

Two videorecordings were taken of each subject's swallows during each of the three conditions. This resulted in six recorded swallows per subject. A total of sixty swallows were recorded for the study. These videorecordings were submitted to a visual temporal analysis. The videotape was played on the Panasonic AG 6200 videorecorder, and viewed on a Grundig PM 050 AV Colour Monitor. The speed at which the tape was viewed was regulated by an edit controller, built into the videorecorder. Utilizing a technique described by Rosenbek et al. (1991), the author viewed each swallow at normal, slowed and frame-by-frame speeds. This was done as many times as was necessary to make a confident judgement.

For each recorded swallow, five durational measures of bolus movement, and specific events within the swallow, were obtained as described by Rosenbek et al. (1991) and Robbins et al. (1992). This entailed initially watching the entire swallow at normal and slowed speeds. Then, each durational measure was timed using the frame-by-frame speed. The number of frames from the onset of the durational measure to its termination, was counted. In South Africa, the PAL television system runs at 25 frames per second. Therefore, the duration of one frame is equal to 0.04 seconds. The frame counts were converted into seconds by multiplying by 0.04.

2.3.2.1 Durational Measures

The five durational measures are listed below. For illustrations of each durational measure, please refer to Appendix C.

1) Duration of maximal velar elevation (DOVE) - DOVE was calculated from the moment the maximal elevatory range of the velum was achieved to the moment the maximal range was released.

2) Duration of Stage Transition (DST) - DST was measured from the moment the bolus head passed the mandibular ramus until maximal hyoid excursion was initiated.

3) Duration of Pharyngeal Response (DPR) - DPR was measured from the initiation of maximal hyoid excursion until the time the hyoid returned to rest.

4) Duration of Pharyngeal Transit (DPT) - DPT was measured from the time the bolus head arrived at the ramus of the mandible to the time the bolus tail passed through the upper oesophageal sphincter.

5) Duration of Upper Oesophageal Sphincter Opening(DUOSO) DUOSO was measured from the first moment at which opening of the upper oesophageal sphincter was seen until the time that the upper oesophageal sphincter closed.

2.3.2.2 Non-Temporal Measures

Several descriptive non-temporal features of the swallows were also analyzed, to determine whether the presence of the nasogastric tubes influenced functional parameters of swallowing. These parameters included the adequacy of bolus containment in the oral cavity, the adequacy of pharyngeal bolus clearance and the integrity of the airway protection mechanisms. These parameters are outlined below, and illustrated graphically in Appendix D.

1)Adequacy of oral bolus containment, demonstrated by the presence or absence of premature leakage of barium into the vallecular space. Leakage is defined by Donner and Jones (1985), as spillage from the mouth into the pharynx prior to the swallow, as a result of incompetence of the faucial isthmus.

2)Adequacy of pharyngeal bolus clearance, demonstrated by the presence or absence of barium residue in the valleculae or pyriform sinuses. Vallecular and pyriform sinus residue was considered present when barium remained in one or both of the vallecular spaces or pyriform sinuses, after the swallow.

3)Adequacy of the airway protection mechanisms, demonstrated by the presence or absence of any laryngeal penetration and/or aspiration. Laryngeal penetration is defined by Donner and Jones (1985) as entry of swallowed material into the larynx either prior to or during swallowing. Aspiration is described as penetration of material into and through the larynx (Donner and Jones, 1985), below the level of the vocal cords.

2.4. Reliability

A method described by Shearer (1982) was utilized to provide a measure of intra and interjudge reliability. Twelve swallows, accounting for 20% of the data, were selected randomly from the data pool of sixty swallows, by a colleague unaquainted with the study. The durational measures of these swallows were analysed 5 weeks later by the original judge, and also by a second judge experienced in the analysis of swallowing. The non-temporal measures were not analysed for reliability as they were evaluated qualitatively rather than quantitatively.

The results of the two judges were compared to gain a measure of interjudge reliability. As a measure of intrajudge reliability, the original and repeat results obtained by the original judge, were compared. In Robbins et al.s' (1992) study, the average intrajudge difference in scoring was 0.091 seconds (2.3 video frames) for all durational measures. Their interjudge reliability averaged a difference of 0.099 seconds (2.5 video frames) for all durational measures. In the present study, a Spearman-Brown correlation co-efficent was applied to the data obtained for the reliability measures.

TABLE 1

Spearman-Brown Correlation Coefficients

for the intra and interjudge reliability

	DOVE	DST	DPR	DPT	DUOSO
INTRA	.8654	.9471	.9607	.6755	.8454
INTER	.7841	-	.8899	.8917	.7791

In the present study the most reliably scored intrajudge measure was DPR. The least reliably scored intrajudge measures was DPT. The average intrajudge difference in scoring was 0.051 seconds (1.27 video frames) for all the durational measures.

The most reliably scored interjudge measure was DPT. The least reliably scored interjudge measure was DUOSO. Unfortunately, the second judge did not score the DST measure, so an interjudge reliability value was not obtained for DST. The average interjudge difference in scoring was 0.085 seconds (2.13 videoframes) for all the durational measures. Both the intra and interjudge average scoring differences compared well with those obtained by Robbins et al. (1992).

2.5 Statistics

For each of the ten subjects, six swallows were recorded, resulting in a total of sixty swallows. Each swallow yielded 5 durational measures and 3 non-temporal measures, resulting in a total of 300 durational measures and 180 non-temporal measures. Mean values for the durational measures, were calculated for the two swallows per condition, and used for statistical analyses. The mean values for the five durational measures were entered into a spread sheet, using the V-Plannner Plus Package (Stephenson Software Incorporated, 1987). Statistical analyses were performed using the EpiInfo Version 6.0 (1994) Statistical Package. One-way Analysis of Variance (ANOVA) (Shearer, 1982), was used to determine whether statistically significant differences existed across the three conditions for each durational variable. Multiple range analyses using the least significant difference test (Snedecor and Cochran, 1980) were performed, to ascertain whether statistically significant temporal differences occurred for individual durational measures between different experimental conditions. The small cell size of the male group did not permit a statistical comparison of gender differences. Male and female means were combined for all the analyses.

The following comparisons were made:

1) condition 1 (no tube) x condition 2 (fine-bore tube)
2) condition 1 (no tube) x condition 3 (wide-bore tube)
3) condition 2 (fine-bore tube) x condition 3 (wide-bore tube)

Since the effects of nasogastric tubes on swallowing have been largely unexplored, the present study was investigating a relatively unresearched area. Thus it was felt reasonable to set the levels of confidence leniently at $p < 0.05$.

CHAPTER 3

RESULTS

Results of the statistical analyses are presented below. The durational measures are presented first, followed by a description of the non-temporal swallowing parameters.

3.1 Gender Differences

There was a trend for the Duration of Pharyngeal Response to be longer in the male subjects than the female subjects for all conditions (Table 2).

Table 2

Duration of Pharyngeal Response mean values (in seconds) for male and female subjects

cond.	Males	Females
1	1.13	1.08
2	1.34	1.23
3	1.65	1.35

In contrast, Robbins et al.(1992) found that the Duration of Upper Oesophageal Sphincter Opening was significantly longer for men, but do not specify whether this is consistent for the 'tube-in' condition.

3.2 Durational Measures

Table 3 summarizes the mean values (in seconds) of the five durational measures for the three conditions.

Table 3

Mean values (in seconds) of the five durational measures for the three conditions

	DOVE	DST	DPR	DPT	DUOSO
cond.					
1	**0.34**	**-0.14**	**1.09**	**0.68**	**0.65**
2	**0.56**	**-0.21**	**1.26**	**0.74**	**0.81**
3	**0.59**	**-0.23**	**1.43**	**0.79**	**0.92**

Table 4 summarizes the results of one-way Analysis of Variance across the three conditions.

Table 4

Results of One-Way Analysis of Variance for the Five Durational Measures

	DOVE	DST	DPR	DPT	DUOSO
f-ratio	**1.479**	**3.060**	**2.710**	**2.681**	**7.475***

*** $p < 0.05$**

3.2.1 Duration of Velar Elevation (DOVE)

Robbins et al. (1992) found that DOVE was significantly shorter in the presence of a manometric tube. Thus it was expected that the presence of the nasogastric tubes would significantly shorten DOVE. The results of one-way Analysis of Variance across the three conditions, were not statistically significant (see Table 4) for this measure. Multiple range analysis using least significant difference (LSD) (Table 5), also failed to show statistically significant differences between any of the three conditions.

The results indicate that nasogastric tubes do not significantly shorten the duration of velar elevation during swallowing. Lack of statistical significance could be due to variability among subjects seen for this measure, as evidenced by the relatively large standard errors of measurement for this measure (Figure 1)

Table 5

Results of Multiple Range Analysis of Duration of Velar Elevation

contrast	difference
1 - 2	-0.02200
1 - 3	-0.25000
2 - 3	-0.03000

*** $p < 0.05$**

The results of the present study are in contrast to Robbins et al.s' (1992) observation that the presence of the manometric tube in the nasal cavities and pharynx, resulted in statistically significant shortening of the DOVE measure. It should be noted however, that while the present results were not statistically significant, the DOVE measures were **greater** in the presence of the nasogastric tubes, than for the 'tube-out' condition (See Table 3 and Figure 1).

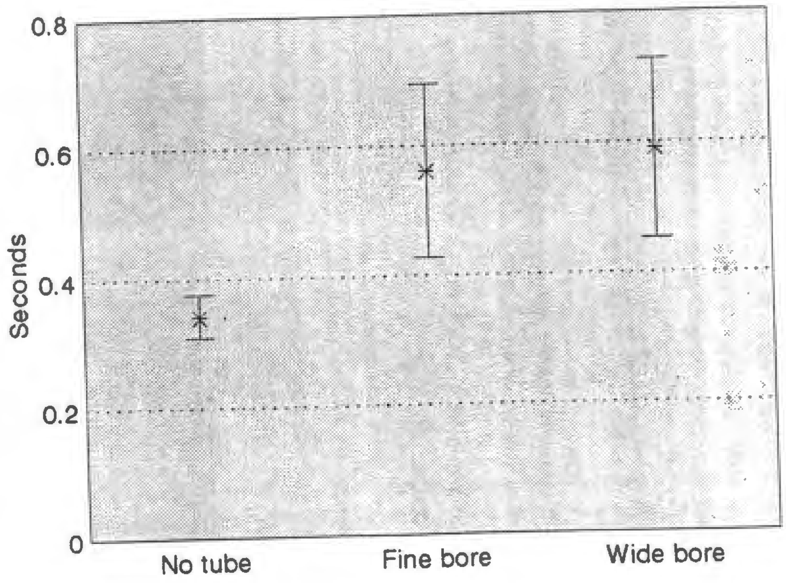


Figure 1 **Duration of Velar Elevation (means and standard errors of measurement)**

3.2.2 Duration of Stage Transition (DST)

It was hypothesized that a longer DST would be associated with the nasogastric 'tube-in' conditions. One way ANOVA failed to reveal any statistically significant differences among the three conditions (Table 4). Multiple Range Analysis revealed a statistically significant difference only between condition 1 and condition 3 (Table 6) suggesting that for normal subjects, DST is significantly shorter for the wide-bore nasogastric tube condition than for the 'tube-out' condition.

Table 6

Results of Multiple Range analyses of Duration of Stage Transition

contrast	difference
1 - 2	0.07200
1 - 3	0.09200*
2 - 3	0.02000

$^*p < 0.05$

As DST is a measure of the onset of pharyngeal response activity relative to the motion of the bolus from the mouth into the pharynx (Robbins et al., 1992), it is interesting to note that the onset of the pharyngeal response relative to bolus motion from the mouth, occurred relatively **earlier** for the wide-bore tube condition than for the 'tube-out' condition. This was shown by the greater negative values for the wide-bore tube condition than for the 'tube-out' condition. An order effect is also evident for this measure. The negative values increase as one goes from the 'tube-out' condition, to the fine-bore, to the wide-bore condition (See Table 3 and Figure 2), although the difference between the two 'tube-in' conditions is relatively small (-0.21 seconds vs -0.26 seconds).

Robbins et al. (1992) did not investigate the effects of the manometric tube on this durational variable, so no comparisons can be made between the present study and theirs.

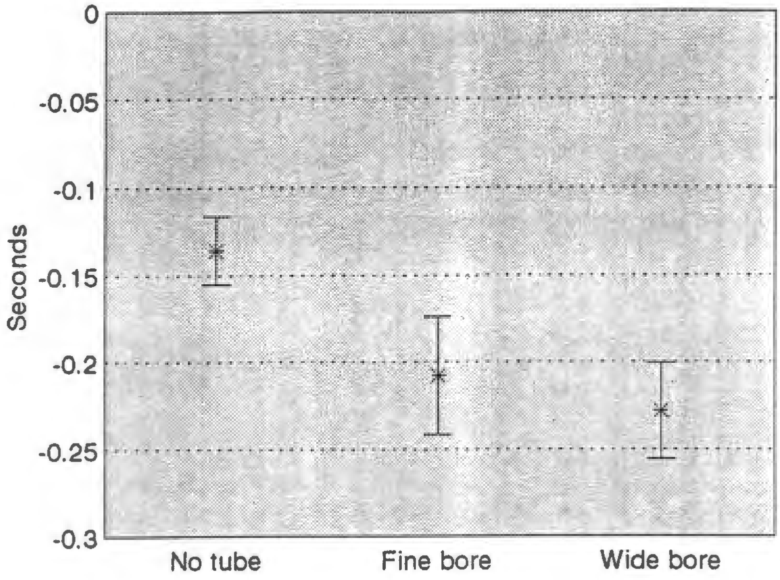


Figure 2 **Duration of Stage Transition (means and standard errors)**

3.2.3 Duration of Pharyngeal response (DPR)

One-way ANOVA revealed no statistically significant differences among the three conditions (See Table 4). Multiple range analysis revealed a statistically significant difference only between conditions 1 and 3, indicating that the presence of a wide-bore nasogastric tube was associated with significantly longer pharyngeal response times in comparison to the 'tube-out' condition (Table 7).

Inspection of the means in Table 3 and Figure 3 reveals that the mean DPR values increase progressively from the 'tube-out' condition to the fine-bore and to the wide-bore tube condition. Similar observations were made by Robbins et al. (1992), who while not specifically studying the DPR, found that components of DPR i.e. Duration of maximal hyoid elevation, and Duration of maximal hyoid anterior excursion, were increased for the 'tube-in' condition.

Table 7

Results of Multiple Range analyses of Duration of Pharyngeal Response

contrast	difference
1 - 2	-0.16800
1 - 3	-0.34000*
2 - 3	-0.17200

*** p < 0.05**

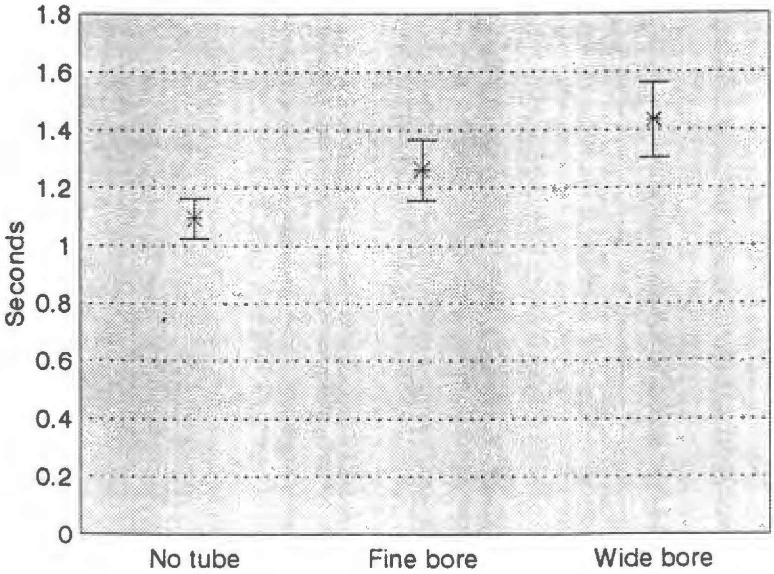


Figure 3 Duration of Pharyngeal Response (means and standard errors)

3.2.4 Duration of Pharyngeal Transit (DPT)

It was expected that the presence of a nasogastric tube would increase pharyngeal transit time. However, no significant differences in pharyngeal transit times were seen across the three conditions using a one-way ANOVA (Table 4). Again, multiple range analysis revealed a statistically significant difference between condition 1 and 3 (Table 8). Although no significant differences were seen between conditions 1 and 2, and 2 and 3, an order effect for the three means was evident, as seen in Table 3 and Figure 4.

Table 8
Results of Multiple Range Analyses of Duration of Pharyngeal Transit

contrast	difference
1 - 2	-0.06400
1 - 3	-0.11400*
2 - 3	-0.05000

* $p < 0.05$

The wide-bore nasogastric tube swallows were associated with longer pharyngeal transit times than the 'tube-out' or fine-bore swallows. The 'tube-out' condition had the shortest pharyngeal transit times. Robbins et al. (1992) did not investigate the effects of the manometric tube on DPT, so no comparisons can be made between their results and those of the present study.

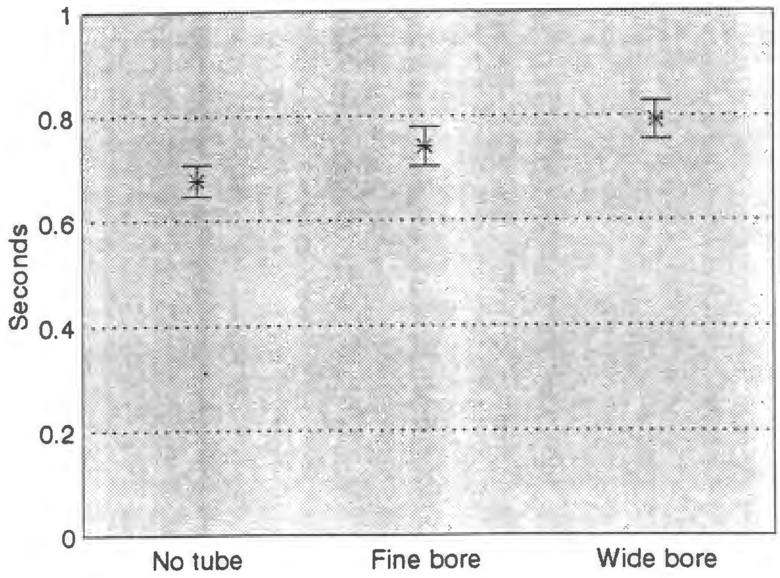


Figure 4 Duration of Pharyngeal Transit (means and standard errors)

3.2.5 Duration of Upper Oesophageal Sphincter Opening (DUOSO)

It was anticipated that the nasogastric tubes would increase DUOSO . One-Way ANOVA revealed statistically significant differences across the three conditions (See Table 4), indicating a significant variance amongst the three conditions for this measure. Multiple Range analysis revealed statistically significant differences between conditions 1 and 2, and 1 and 3 (Table 9).

Table 9

Results of Multiple Range Analyses of Duration of Upper Oesophageal Sphincter Opening

contrast	difference
1 - 2	-0.16000*
1 - 3	-0.26800*
2 - 3	-0.10800

* $p < 0.05$

The mean values increased gradually through condition 1 to condition 3, as depicted in Table 3 and Figure 5. These results indicate that both fine and wide-bore nasogastric tubes significantly increase the DUOSO in comparison to the 'tube-out' condition. Similar findings were made by Robbins et al.(1992) who report that DUOSO was significantly longer for the manometric 'tube-in' condition.

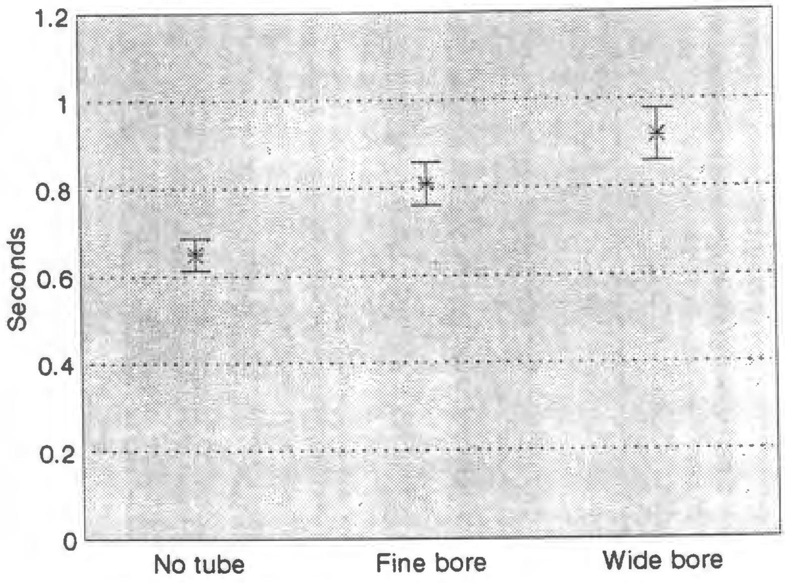


Figure 5 **Duration of Upper Oesophageal Sphincter Opening (means and standard errors)**

3.2.6 Summary

The results of the durational measures analyses, indicate that the presence of a wide-bore nasogastric tube significantly increased the values of 3 of the 5 temporal measures (DPR, DPT and DUOSO) in comparison to the 'tube-out' condition. The durational measures were increased, thus leading to slowing down of bolus or swallowing motion. Although some slowing was also seen for the durational measures as a function of the fine-bore nasogastric tubes, these changes were statistically significant, only for the DUOSO measure. The only measure that was significantly shorter for the wide-bore tube condition than for the 'tube-out' condition was DST.

3.3 Non- Temporal Measures

The non-temporal parameters were analysed using frequency counts.

3.3.1 Adequacy of bolus containment

Premature leakage of the barium bolus was seen in 5 subjects (See Figure 6). In 3 subjects this was also observed as part of the normal swallowing pattern in the absence of the nasogastric tubes. In the remaining two subjects, premature leakage was seen only for the fine-bore nasogastric 'tube-in' condition. It was difficult to determine the exact amount of barium leakage, but the quantities appeared small.

As premature leakage was seen in 3 subjects' **normal** swallowing in the absence of a nasogastric tube, and only small quantities of barium leaked into the pharynx, the presence of a nasogastric tube in the pharynx does not appear to interfere with bolus containment.

3.3.2 Adequacy of pharyngeal bolus clearance

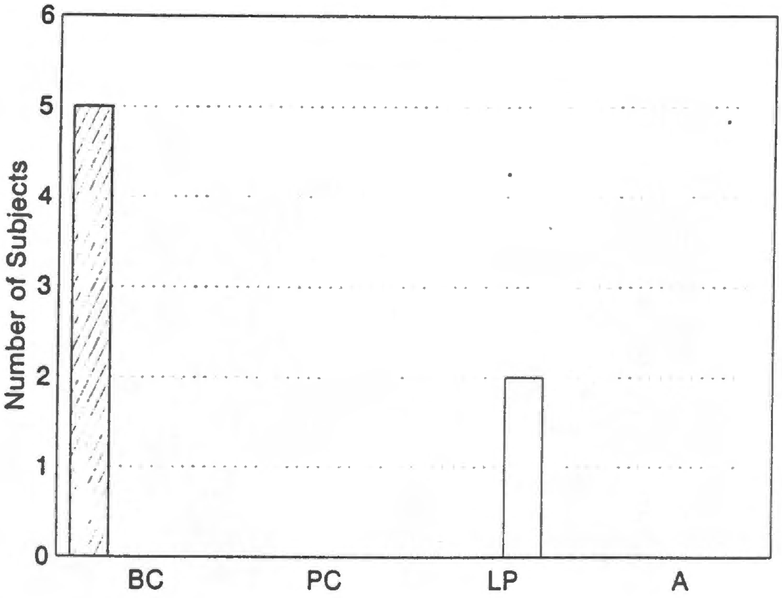
No subject demonstrated bolus residue in the valleculae or pyriform sinuses for any of the three conditions (See Figure 6). This indicates that nasogastric tubes do not seem to interfere with pharyngeal bolus clearance.

3.3.3 Adequacy of airway protection

No subject demonstrated aspiration, i.e. entry of the bolus below the level of the true vocal cords (Robbins et al. 1992) (Figure 6). Penetration of barium into the laryngeal vestibule was seen in 2 subjects (Figure 6). In one subject this was seen only for condition 1 (no tube-in condition). In the second subject, laryngeal penetration was seen during normal swallowing, and for the wide-bore tube condition. These results suggest that nasogastric tubes do not influence airway protection.

3.3.4 Summary

These results suggest that in young, normal adults, the non-temporal swallowing parameters are not influenced by the presence of a nasogastric tube. Thus the **function** of the swallowing mechanism, specifically pharyngeal clearance and airway protection, does not appear to be affected by the presence of a nasogastric tube in the pharynx.



BC - Bolus Containment ; PC - Pharyngeal Clearance ; LP - Laryngeal Penetration ; A -Aspiration

Figure 6 **Frequency of non-temporal swallowing parameter changes as a function of nasogastric tubes**

CHAPTER 4

DISCUSSION

The purpose of this study was to investigate whether fine and wide-bore nasogastric tubes interfere with swallowing in young, normal subjects. This was assessed by comparing ten subjects' normal swallowing patterns in the absence of a nasogastric tube, with their swallowing under two nasogastric 'tube-in' conditions. Specific aspects of swallowing, namely temporal measures of bolus movement and temporal measures of specific events within the swallow, were analysed.

The major finding of this study, is that the presence of a wide-bore nasogastric tube in the naso- and oropharynx, caused significant slowing of bolus movement, and of events within the swallow pattern of young normal adults. The effects of the fine-bore nasogastric tubes on these measures were generally less marked, and the presence of a fine-bore nasogastric tube did not significantly interfere with normal swallowing in young adults. While wide-bore nasogastric tubes did not appear to compromise swallowing functionally, they did slow normal swallowing in healthy, young adults to a significant degree.

4.1 Gender Differences

There was a trend for the Duration of Pharyngeal Response (DPR) to be longer in males than in females. This finding may be attributable to the fact that males have larger pharyngeal dimensions than females. Consequently, the DPR, which includes bolus motion through the pharynx, may be increased in males, as the bolus has to traverse a larger cavity in males than in females. Robbins et al. (1992) found that the Duration of Upper Oesophageal Sphincter Opening (DUOSO) was significantly longer for women than for men, but do not specify whether this finding is consistent for both the 'tube-out' and 'tube-in' conditions. Their finding was not replicated in the present study. Possible explanations for the lack of statistically significant gender differences in the present study, are the uneven sex ratio and the small subject numbers in general. In Robbins et al.s' study, there were equal numbers of male and female subjects (40 males and 40 females). In the present study there were 7 females and 3 males. The uneven male/female ratio and small sample size may have negatively impacted upon the validity of this finding. It is difficult therefore, to draw comparisons between the present study and that of Robbins et al. (1992). A further investigation in which equal and larger numbers of both sexes are studied, is warranted, to determine whether any significant differences exist in swallowing between males and females with nasogastric tubes in situ.

4.2. Durational Measures

4.2.1 Duration of Velar Elevation (DOVE)

No statistically significant differences were found for this measure. This indicates that neither the presence of the tube, nor the tube size significantly interferes with velar elevation. The large standard error of measurement, seen for this measure (Figure 1) suggests large variability amongst the subjects. This might have contributed to the lack of statistical significance for this measure. Despite this lack of significant difference, DOVE was **longer** in the presence of the nasogastric tubes than for the 'tube-out' condition. This trend is not consistent with Robbins et al.s' (1992) finding that DOVE was significantly **shorter** for the manometric 'tube -in' condition than for the 'tube-out' condition. Robbins et al. do not provide an explanation for this observation.

In the present study, the longer DOVE in the presence of the nasogastric tubes could possibly be attributed to several factors. A most likely reason could be the elicitation of the gag reflex. During nasogastric tube insertion, eight of the ten subjects gagged when the tubes (both fine and wide-bore) were passed into the pharynx, and contacted the posterior pharyngeal wall. Gagging was also observed in 5 subjects while swallowing with the tube in situ (2 with the fine-bore tube and 3 with the wide -bore tube).

The gag reflex generally occurs in response to a noxious stimulus presented to the posterior pharyngeal wall or the base of the tongue (Logemann, 1986c). The response to the stimulus, is a sudden and strong contraction of the velum and pharyngeal constrictors, in an attempt to eject the noxious or uncomfortable stimulus from the pharynx (Logemann, 1986c). The nasogastric tubes may have stimulated the gag reflex, and resulted in velar elevation dissimilar to the velar elevation that occurs during normal swallowing.

The presence of a nasogastric tube could also result in premature velar elevation. Premature velar elevation was noted in seven of the ten subjects with the 'tube-in' conditions, irrespective of tube size. This may occur because of sensory feedback in the naso- and oropharynx arising from the tube. The presence of the tube may simulate that of a bolus in the pharynx which leads to an earlier triggering of the sequence of events that normally occur during swallowing, including velar elevation.

When a liquid bolus is held in the mouth in preparation for swallowing, the back of the tongue and soft palate approximate each other to prevent fluid running from the back of the mouth and prematurely entering the oropharynx, prior to triggering of the airway protection mechanisms. Dantas et al. (1990) propose that the occlusive squeeze of the posterior tongue and velum have the physiological function of a sphincter, termed the glossopalatal sphincter (GPS). As the bolus passes through the entrance of the oropharynx, initiation of swallowing occurs and the soft palate elevates, enabling unobstructed entry of the bolus into the pharynx (Dantas et al.,1990). Premature velar elevation could interfere with the glossopalatal sphincter, leading to premature spill of a liquid bolus into the pharynx. It was therefore interesting to note, that in only one subject, premature velar elevation was associated with premature leakage of the bolus into the pharynx. All the subjects had normal tongue strength and mobility, which probably contributed to maintaining and containing the bolus in the oral cavity. It would be interesting to evaluate the adequacy of oral bolus containment with nasogastric tubes in-situ, in subjects with mechanical or neurological lingual deficits. The clinical implications of possible reduced bolus containment are significant, as premature spill of a bolus into the pharynx is often associated with early aspiration because the larynx is unprotected (Logemann, 1986 in Dantas et al. 1990).

4.2.2 Duration of Stage Transition (DST)

In the present study, the Duration of Stage Transition or onset of the pharyngeal swallow response, was found to be significantly shorter for the wide-bore nasogastric tube condition than for the 'tube-out' condition. More negative group mean values for DST were obtained for the wide-bore tube condition (-0.23 seconds) than for the 'tube-out' condition (-0.14 seconds). This indicates that the onset of pharyngeal swallow response, relative to the motion of the bolus from the mouth to the pharynx, occurred significantly earlier with the wide-bore tube in situ. During normal swallowing, DST group mean values are usually negative in young adults, as the initiation of maximal hyoid excursion occurs before the bolus head reaches the ramus of the mandible (Robbins et al., 1992). With increasing age there is a gradual change from negative DST values in young adults, to more positive group mean values in older individuals. In young adults, initiation of maximal hyoid elevation occurs **before** the bolus reaches the mandibular ramus. However, in older people initiation of hyoid elevation occurs **after** the head of the bolus arrives at the ramus of the mandible (Robbins et al., 1992). Robbins et al. (1992) did not specifically investigate the influence of the manometric tube on the DST measure.

It was expected that a nasogastric tube would delay triggering of the pharyngeal swallow. However, the opposite occurred. Earlier hyolaryngeal excursion and initiation of the pharyngeal response was observed for the 'tube-in' conditions than for the 'tube-out' condition. It is possible that this early hyolaryngeal excursion occurs as an 'anticipatory' behaviour in response to the presence of the nasogastric tube in the pharynx. Kidder et al.(1994) critically examined the technique of nasoendoscopy for the evaluation of cervical dysphagia. Anticipatory pharyngeal and laryngeal movements, or 'baby' pharyngeal contractions were observed. These contractions were considered to be attempts to avoid impending discomfort during the nasoendoscopic examination.

The technique of nasoendoscopic intubation is similar to nasogastric intubation with the tube being passed transnasally into the pharynx. It is possible that the earlier hyolaryngeal excursion seen in the present study for the 'tube-in' conditions, bears a similarity to the anticipatory pharyngeal and laryngeal movements that Kidder et al. (1994) observed during nasendoscopy. The reason for this early hyolaryngeal excursion and pharyngeal response triggering, may be protective. An earlier initiation of hyolaryngeal elevation results in earlier closure of the laryngeal vestibule. This effectively prevents any laryngeal penetration or aspiration. Earlier pharyngeal response triggering and airway protection may thus compensate for the invasive nature of the wide-bore nasogastric tube in the pharynx, by preventing any airway penetration.

In addition, the presence of the nasogastric tube in the pharynx may mechanically stimulate the pharyngeal wall, and as a result, lead to triggering of a pharyngeal swallow response. Stimulation of the anterior faucial pillars, posterior tongue and epiglottis, as well as the larynx, has been shown to trigger swallowing (Shaker et al., 1994). Previous studies have demonstrated that mechanical stimulation of the pharyngeal wall in animals (Patterson et al., 1986 in Shaker et al., 1994), and injection of water into the human pharynx (Nishino et al., 1987 in Shaker et al., 1994; Nishino, 1993) triggers swallowing. Shaker et al.(1994) found that mere contact of water with the posterior pharyngeal wall triggered swallowing, despite the fact that the subjects were asked to resist swallowing. These authors speculate that the pharyngeal swallow response triggered by this stimulation, may help prevent aspiration by activating the swallow-induced glottal closure mechanism. This in turn seals off the airway and prevents any possible aspiration of material.

If the simple contact of water against the posterior pharyngeal wall can trigger swallowing, it seems likely that the presence of a nasogastric tube in the pharynx can do the same. The passage of a nasogastric tube places it in contact with the velum, posterior pharyngeal wall, and possibly with the epiglottis and larynx, depending on tube size or positioning. It is thus possible that the significantly earlier pharyngeal response triggering, observed in the wide-bore nasogastric tube condition, is functionally related to the pharyngeal swallows that Shaker et al. (1994) describe. These swallows are triggered by mechanical stimulation to the pharynx. Their function appears to be airway protection against pharyngeal reflux of gastric contents, as well as inadvertent spill-over of oral contents into the pharynx, during the preparatory phase of the swallow (Shaker et al., 1994).

Mannson and Sandberg (1975 a and b, in Nishino, 1993) suggest that stimulation of the pharyngeal and laryngeal regions is needed to repetitively elicit swallowing. Pharyngeal, laryngeal and oesophageal regions are well-supplied with sensory receptors that are active during swallowing (Nishino, 1993). Peripheral feedback from these areas facilitates the voluntary elicitation of swallowing, and peripheral afferents may trigger swallowing, and can control the complete motor sequence through sensory feedback.

The space-occupying nature of the nasogastric tube may simulate the sensation of a bolus in the pharynx, leading to a feeling of fullness and incomplete pharyngeal clearance. Thus, in addition to the pharyngeal response being triggered earlier as an airway protection mechanism, the pharyngeal response may also be triggered to clear the pharynx of the sensation of a perceived 'bolus' associated with the 'tube-in' conditions. This notion is supported by the number of double swallows (a second swallow after the bolus had been cleared from the pharynx) seen for the two 'tube-in' conditions. In six of the ten subjects, double swallows were observed both for the fine and wide-bore tube conditions. It appears that both the space-occupying nature of the tubes, as well as the mechanical stimulation of the pharyngeal tissues by the tubes, may have triggered swallows, even after the barium bolus was cleared.

Although Robbins et al. (1992) did not investigate any changes in DST in the presence of a manometric tube, they noted that in normal oropharyngeal sensorimotor systems (even in older individuals), no subjects aspirated with the manometric tube in situ, and airway protection was achieved. Similar findings were made in the present study. This suggests that a normal swallowing mechanism is able to compensate for the presence of a nasogastric tube during swallowing. It is possible that this compensation is related to the earlier triggering of the pharyngeal swallow, which enhances and expedites airway protection.

It would be interesting to investigate whether dysphagic subjects or those with compromised oropharyngeal sensorimotor systems have longer Duration of Stage Transitions and slower triggering of the pharyngeal swallow response. A longer DST is associated with delayed triggering of the swallowing reflex (Robbins et al., 1992). The swallowing reflex is one of the most important functions subserved by the pharynx (Nishino,1993), and absence of adequate swallowing reflex activity greatly increases the chance of pulmonary aspiration (Logemann, 1986; Logemann, 1987 in Robbins et al., 1992).

In dysphagic patients the presence of the nasogastric tube may result in delayed triggering of the pharyngeal swallow response. This would have important clinical implications, as dysphagic patients are most likely to be fed via nasogastric tube. Should this hypothesis be proved correct, alternatives to nasogastric feeding, in the interests of pulmonary health, may be necessary. It is vital therefore, to ascertain the effects of nasogastric tubes on dysphagic patients' swallowing efficiency, and particularly on airway protection.

It would also be interesting to examine the long-term effects of nasogastric tubes on the triggering of the pharyngeal response, both in young, normal subjects and dysphagic subjects. The early initiation of hyolaryngeal excursion relative to bolus motion, seen in the present study, may be the result of acute sensory changes in the pharynx caused by intubation discomfort, and the invasive presence of the nasogastric tube. One may speculate that with sensory accommodation to the tube, this earlier pharyngeal response triggering may lessen over time, and normal timing of hyolaryngeal elevation relative to bolus motion, may be re-established. Alternatively, prolonged accommodation of the nasogastric tube, may result in deterioration of swallow reflex activity, which could hinder recovery of normal swallowing patterns in dysphagic patients, and increase the likelihood of aspiration. Studies examining the long-term effects of nasogastric tubes on swallowing recovery as well as frequency of aspiration in dysphagic patients are warranted.

4.2.3 Duration of Pharyngeal Response (DPR)

In the present study, the DPR was significantly longer for the wide-bore tube condition (1.43 seconds) than for the 'tube-out' condition (1.09 seconds). Interestingly, Robbins et al. (1992) found that the DPR was significantly increased for the manometric 'tube-in' condition, only in subjects older than seventy. In the present study, a significant lengthening of the DPR was seen in **young** adults, but only for the wide-bore tube condition. It is difficult to compare Robbins et al.s' findings with the results of the present study, because of the methodological differences regarding tube size and description. It is possible that the manometric tube utilized by Robbins et al. (1992) was nearer in dimension to the fine-bore tube utilized in the present study, which did not significantly increase the DPR. An age-related change in the ability to compensate for the presence of a nasogastric tube should be investigated, to determine whether this is a consistent finding for other age groups, or whether fine-bore nasogastric tubes do significantly increase pharyngeal response duration in older individuals.

It appears that wide-bore nasogastric tubes lengthen DPR primarily by two factors: earlier and longer hyolaryngeal elevation; and a longer duration of upper oesophageal sphincter opening. To clarify this statement, it is necessary to discuss the swallowing events that occur during the pharyngeal response phase. Two important components of the pharyngeal response phase are the Duration of Hyoid Maximal Elevation (DOHME) and the Duration of Hyoid Maximal Anterior Excursion (DOHMAE) (Robbins et al., 1992). These two components lift (DOHME) and move the hyolaryngeal complex forward (DOHMAE), positioning the larynx under the base of the tongue. This position helps protect the airway from aspiration of material.

Another pharyngeal stage variable is the opening of the upper oesophageal sphincter (Donner et al., 1985). Opening of the upper oesophageal sphincter is dependent on hyolaryngeal elevation and anterior excursion which pulls the cricoid lamina away from the posterior pharyngeal wall and opens the upper oesophageal sphincter before bolus arrival (Robbins, 1992). Thus, the hyolaryngeal traction force serves to open the upper oesophageal sphincter (Robbins, 1992).

Robbins et al. (1992) found that the three pharyngeal stage variables of DOHME, DOHMAE and DUOSO were all significantly increased for the manometric 'tube-in' condition. The present study did not specifically investigate DOHME and DOHMAE. However, DPR, of which DOHME and DOHMAE are both components, was increased for the wide-bore tube condition. Thus, it seems likely that DOHME and DOHMAE were also increased in the present study. DUOSO was found to be significantly longer for both the wide and fine-bore tube conditions in the present study. Robbins et al. (1992) found that the manometric tube assembly partially obstructed the upper oesophageal sphincter. Thus bolus transit through the upper oesophagus was slowed, and the duration of upper oesophageal sphincter displacement needed to permit bolus transit, was increased. Since the hyolaryngeal complex was instrumental in opening the upper oesophageal sphincter, it needed to remain elevated for longer to maintain prolonged upper oesophageal sphincter opening. Thus the durations of the mechanical events which opened the upper oesophagus (DOHME and DOHMAE) also increased.

A nasogastric tube will also obstruct the upper oesophageal sphincter opening, resulting in a similar sequence of events described by Robbins et al. (1992) i.e. slow bolus transit through the upper oesophagus, leading to increased duration of upper oesophageal sphincter displacement, which requires increased duration of hyolaryngeal elevation. Thus while the presence of a wide-bore nasogastric tube did not mechanically interfere with hyolaryngeal elevation, it did interfere with upper oesophageal sphincter opening, which indirectly influenced hyolaryngeal movement.

In addition to the **longer** hyolaryngeal elevation discussed above, the DPR was also increased by the **earlier** hyolaryngeal elevation. Early hyolaryngeal elevation was associated with a shorter Duration of Stage Transition, and earlier triggering of the pharyngeal swallow, seen in this study for the wide-bore tube condition. Thus the overall length of hyolaryngeal elevation was increased for the wide-bore tube condition. The increased hyolaryngeal elevation and the increased duration of upper oesophageal sphincter opening both contributed to the increase in DPR seen for the wide-bore nasogastric tube in the present study.

4.2.4 Duration of Pharyngeal Transit (DPT)

In the present study, the presence of the wide-bore nasogastric tube significantly increased the DPT. Robbins et al. (1992) did not specifically examine this swallowing variable in their study. The most apparent explanation for the finding of increased DPT for the wide-bore tube condition in the present study, is that the wide-bore nasogastric tube is space-occupying and partially obstructs the pharyngeal cavity and the upper oesophageal sphincter. Free and unobstructed passage of the barium bolus through this lumen, is thus not possible. The time taken to pass through the pharynx and upper oesophageal sphincter is therefore lengthened. The larger the tube circumference, the more space the tube occupies in the pharynx, and the longer the bolus will take to traverse this cavity. One may speculate that with the nasogastric tube in situ, the volume capacity of the pharyngeal cavity is reduced. It would be useful to biomechanically and manometrically evaluate the impact of a nasogastric tube on pharyngeal structure, shape and function.

This slowing of bolus transit associated with a wide-bore nasogastric tube, may have clinical implications for dysphagic patients. As suggested previously, increased pharyngeal transit time may negatively impact upon swallowing recovery and rehabilitation, by increasing the overall swallowing time in a patient who fatigues easily. Dysphagic patients may be unable to sustain the increased muscle activity required to maintain longer hyolaryngeal elevation and upper oesophageal sphincter opening, associated with a wide-bore nasogastric tube in the pharynx. It is possible that by fatiguing the dysphagic swallowing mechanism, the likelihood of the patient aspirating increases. The hypothesis that an increase in DPT is associated with increased frequency of aspiration in nasogastrically fed dysphagic patients, needs to be investigated in more detail.

4.2.5 Duration of upper oesophageal sphincter opening (DUOSO)

The most striking finding for the DUOSO measure, was that both fine and wide-bore nasogastric tubes significantly lengthen it. This was the only durational measure which was significantly affected by the presence of the fine-bore nasogastric tube. Robbins et al.s' (1992) findings of significantly increased DUOSO in the manometric 'tube-in' condition, agree with the findings of the present study.

A number of factors may contribute to the observed lengthening of DUOSO for both nasogastric tube conditions, in the present study. In order for normal upper oesophageal sphincter opening to occur and permit passage of a bolus into the oesophagus, four criteria must be met.:

1) relaxation of the muscle tone
2) compliant tissue
3) traction force supplied by sufficient hyolaryngeal excursion

4) pulsion force imparted by the bolus (McConnel ,1988 in Robbins, 1992)

This discussion will only focus on the last two criteria. The present study demonstrated that the pharyngeal response duration, of which hyolaryngeal excursion constitutes a component, increased significantly for the wide-bore tube condition. When the nasogastric tube is in position, prolonged hyolaryngeal excursion is needed to maintain sufficient traction force to sustain upper oesophageal sphincter opening. The upper oesophageal sphincter opening is maintained longer, both to accommodate passage of the bolus through the obstructed oesophageal lumen (Robbins et al., 1992), and to accommodate the nasogastric tube traversing it.

As demonstrated in the present study, the DPT of a barium bolus is significantly slowed by the presence of a wide-bore nasogastric tube in the pharynx. The upper oesophageal sphincter has to remain open for longer to accommodate the slowed bolus transit. Both hyolaryngeal excursion and the traction force exerted by the bolus on the upper oesophageal sphincter, are necessary to maintain upper oesophageal sphincter opening. Prolonged hyolaryngeal excursion, and a prolonged pulsion force exerted by the slowed bolus flow, contribute to lengthening the DUOSO for the wide-bore tube condition.

It is interesting that even the fine-bore nasogastric tube lead to significant lengthening of DUOSO, as bolus transit and hyolaryngeal excursion were not significantly increased for the fine-bore tube condition in the present study. However, Robbins et al. (1992) note that with a manometric tube assembly in place, the upper oesophageal sphincter is partially open to accommodate the tube, even during rest. Even the narrow circumference of the fine-bore tube contributes to partial upper oesophageal sphincter opening during rest, and results in a significant overall increase in DUOSO.

As noted earlier, Fay et al. (1991) and Allison et al. (1992) suggest that the presence of a tube traversing the upper and lower oesophageal sphincters could disrupt the normal cough and swallow mechanisms, and increase the risk of gastroesophageal reflux and aspiration. The fine and wide-bore nasogastric tubes may contribute to disrupting the cough and swallow mechanisms by prolonging upper oesophageal sphincter opening. It would be interesting to perform manometric studies comparing upper oesophageal sphincter pressure for fine and wide-bore nasogastric tube conditions, both in normal and dysphagic subjects. This could help clarify the interaction between a nasogastric tube (and its size) and the function of the upper oesophageal sphincter. It would also be interesting to examine the frequency of aspiration in dysphagic patients, as a function of nasogastric tube-induced changes in upper oesophageal sphincter pressure.

4.3 Non- Temporal Measures

4.3.1 Adequacy of bolus containment

Premature leakage of the barium bolus from the mouth into the pharynx was observed in five of the subjects i.e. 50% of the subject group. While this percentage seems high, one should note that in three of the subjects, the premature leakage was seen during normal swallowing for the 'tube-out' condition. In the remaining two subjects, leakage was seen only for the fine-bore tube condition. No premature leakage was observed in any subject for the wide-bore tube condition. Also the barium quantities that leaked into the pharynx appeared to be small.

Leakage from the mouth into the pharynx may be due to a reduced glossopalatal seal, as suggested by Dantas et al. (1990). Premature velar elevation which could interfere with the glossopalatal sphincter was seen in seven of the ten subjects in the present study for the 'tube-in' conditions. However, in only one subject was premature velar elevation associated with premature leakage of the bolus into the pharynx. As noted earlier, there was a trend in those with premature velar elevation to hold the bolus more anteriorly in the mouth, thus preventing any bolus spill in to the pharynx. Since premature leakage was observed more frequently during normal swallowing, than during 'tube-in' swallows, one may conclude that the presence and size of nasogastric tubes does not significantly interfere with the adequacy of oral bolus containment in young, normal adults. It would be interesting to assess bolus containment with nasogastric tubes in situ, in subjects with tongue weakness caused by motor or structural deficits. Reduced tongue strength might prevent anterior bolus holding, resulting in a greater frequency of premature leakage.

4.3.2 Adequacy of Pharyngeal bolus clearance

No subject demonstrated bolus residue in the vallecular spaces or pyriform sinuses for any of the experimental conditions. This suggests that nasogastric tubes do not interfere with pharyngeal bolus clearance. This was interesting in light of the slowed bolus transit seen for the wide-bore tube condition. One might expect a slow bolus transit to be associated with reduced pharyngeal clearance. However this did not occur in the present study. It would be interesting to investigate whether there is a relationship between slow pharyngeal bolus transit and pharyngeal residue, in nasogastrically-fed older subjects or those with pharyngeal weakness arising from structural or motor deficits.

4.3.3 Adequacy of airway protection

No subject demonstrated aspiration in the present study. Laryngeal penetration was seen in two subjects. In one subject, penetration occurred during normal 'tube-out' swallowing. In the other subject, penetration was seen during the 'wide-bore' tube condition. In both subjects, the barium was subsequently cleared from the laryngeal vestibule. These findings are similar to those of Robbins et al. (1992) who noted that no normal subject aspirated for the manometric 'tube-in' condition. They suggest that a normal oropharyngeal sensorimotor system, even in older individuals, is able to functionally compensate for an invasive state such as the presence of a tube during swallowing.

The absence of aspiration may be related to the earlier hyolaryngeal excursion seen in the present study. As suggested previously, early hyolaryngeal excursion and pharyngeal response triggering may have a protective function. Early hyolaryngeal excursion results in earlier elevation and closure of the laryngeal vestibule, effectively preventing any laryngeal penetration or aspiration. Thus, the early hyolaryngeal excursion and pharyngeal response triggering seen in the present study, may in fact be the functional compensation mechanism Robbins et al. (1992) describe. It would be interesting to investigate whether this compensatory mechanism exists in dysphagic patients and those with oropharyngeal sensorimotor dysfunction. It is possible that the presence of a nasogastric tube may delay hyolaryngeal elevation and pharyngeal response triggering in dysphagic patients. Delayed triggering of the pharyngeal swallow is associated with a greatly increased chance of aspiration (Logemann, 1986: Logemann, 1987 in Robbins et al. 1992). Thus the dysphagic swallowing mechanism may not be able to functionally compensate for the invasive state of the nasogastric tube.

4.4 Clinical implications of the study

The findings of this study have important clinical implications for non-oral feeding. Firstly, it appears that if the option of nasogastric feeding is utilized, all patients regardless of age or the status of their swallowing mechanisms, should be fed via a fine-bore nasogastric tube. The present study demonstrated that wide-bore nasogastric tubes cause significant slowing of bolus movement and specific events within the swallowing patterns of normal, young adults. The effects of nasogastric tubes on swallowing in dysphagic patients, have yet to be studied. However, if wide-bore nasogastric tubes interfere with swallowing in young, normal adults, it seems highly probable that they will detrimentally affect swallowing, and possibly swallowing recovery in dysphagic patients. Thus if nasogastric feeding is implemented, fine-bore nasogastric tubes should be utilized as a matter of course from the outset. Although fine-bore nasogastric tubes were found to have a less marked effect on young, normal swallowing patterns in the present study, it is possible that they will have a deleterious effect on a dysphagic swallowing mechanism. In addition, the long term effects of nasogastric tubes on the function of the swallowing mechanism still need to be investigated. It seems probable that nasogastric tubes may interfere with swallowing recovery for many of the reasons highlighted in the present study.

Ideally therefore, alternatives to nasogastric feeding should be utilized whenever possible. Certainly, PEG feeding should be considered in all patients requiring long-term non-oral feeding. PEG feeding eliminates the need for any tube in the pharynx, and may consequently facilitate swallowing recovery. Moran and Frost (1992) suggest that patients fed via PEG recover speech and swallowing faster than those fed via nasogastric tube. This however, needs to be objectively documented. Usually PEG feeding is reserved for patients with long-standing dysphagia i.e. more than 30 days (Kirby et al., 1995). However, Norton et al. (1996) found that gastrostomy feeding initiated 14 days post-acute CVA, was associated with a significant reduction in mortality. This lends support to PEG feeding being utilized in patients presenting with acute dysphagia subsequent to CVA or head injury. In certain Northern Hemisphere centres, PEGs are inserted prior to operating on patients requiring head or neck resections or plastic and reconstructive surgery of the oral and facial areas (DR J. Van Zyl, Personal Communication). This is done to minimize the discomfort caused by the indwelling nasogastric tubes, which have also been found to hamper both tissue and functional recovery. An important area of research is to evaluate the effect of nasogastric tubes on swallowing recovery in different neurological or surgical patient populations. A comparison of patients fed via nasogastric tubes with those fed via PEG, would help determine whether PEG feeding does indeed encourage more rapid swallowing recovery than nasogastric tube feeding, as suggested by Moran and Frost (1992).

4.5 Limitations of the study and indications for future research

A number of limitations exist in this study which need to be adequately addressed in future investigations.

Firstly, a small sample size (N=10) was used. Although the small sample size was felt to be adequate because the study was a pilot study and a within-subjects design was utilized (Ventry and Schiavetti, 1980), larger sample sizes of approximately 20 subjects per group as utilized by Robbins et al. (1992) might have increased the reliability of the study. Fortunately, the small sample size was balanced by the small standard errors of measurement, seen for all the durational measures, except for DOVE. The small standard errors of measurement indicate that there was little variability over repeated measurements, and suggests that measurements were precise and reliable (Ventry and Schiavetti, 1980).

Secondly, there was an uneven male/female sex ratio. While no significant sex differences were evident in this study, this result may have been different had more equal numbers for each sex existed. Hence, the uneven sex ratio may have contributed to the lack of statistical significance between the genders. Robbins et al. (1992) used equal male and female numbers (40 males/40 females) and found statistically significant gender differences for certain durational measures. Future studies should therefore aim for equivalent male and female subject numbers.

Thirdly, only young, normal adults between the ages of 20 and 27 years were studied. Investigating one age group of adults only, was chosen to eliminate any age-related swallowing changes which may have interacted with the experimental conditions. However, further studies need to investigate other age groups, to determine the effects of nasogastric tubes on the older swallowing mechanism. As the present study only investigated normals, subjects with abnormal swallowing mechanisms and dysphagia should be studied in the future, to ascertain what effects the tubes have on their swallowing and on their ability to recover swallowing.

Fourthly, the nasogastric tubes remained in-situ for very limited time periods (a maximum of 3 to 5 minutes per intubation), and were then removed. The intubation procedure and the short-term presence of the tubes may have lead to a number of short-term sensory changes in the oro- and nasopharynx. In addition, there may have been a carry-over effect from the first to the second nasogastric intubation, affecting performance on the second 'tube-in' condition swallows. Hopefully, this was minimized by randomizing the sequence of the 'tube-in' conditions.

The possible short-term sensory changes might have contributed to the observed durational changes in swallowing seen in the present study. Consequently, it is important to investigate the long-term effects of both wide-bore and fine-bore nasogastric tubes on swallowing function. It is possible that over extended time periods, even fine-bore nasogastric tubes may alter swallowing physiology in young, normal swallowing mechanisms. It is also possible that over an extended time period, adaptation to the tube may occur, resulting in **less marked** effects on swallowing physiology than seen in this study. This aspect could be studied in patients with normal swallowing mechanisms, who require nasogastric feeding for reasons other than dysphagia. The swallowing patterns of these patients could be studied using a similar approach to that described in the present study. Swallow studies could be conducted prior to nasogastric intubation, then at regular intervals during the intubation period. Durational and functional swallowing changes could be analyzed, and the long-term effects of nasogastric tubes assessed.

4.6 Conclusions

The main conclusion drawn from the present study, is that wide-bore nasogastric tubes caused significant changes in four out of five durational measures of swallowing in young, normal adults. Fine-bore nasogastric tubes were not found to have a significant effect on these swallowing measures. The presence of wide-bore nasogastric tubes in the pharynx made swallowing **less efficient** in young, normal adults. The reduced efficacy occurred because of generalized slowing of bolus movement (DPT) and specific events within the swallow (DOVE, DPR and DUOSO). The only durational measure that could be considered "improved" by the presence of the wide-bore tube, was DST (triggering of the pharyngeal swallow response). The pharyngeal swallow response was triggered earlier for the wide-bore tube condition than the 'tube-out' condition, leading to earlier airway protection. However, this should be regarded as a compensation for the presence of the wide-bore tube rather than an indication of the improved pharyngeal response efficiency.

The wide-bore nasogastric tube did not interfere with the **function** of a young, normal swallowing mechanism. The function of the swallowing mechanism is to protect the airway from entry of food, liquid or saliva particles, and to transport ingested material and saliva from the mouth to the stomach (Dodds et al., 1988). The wide-bore nasogastric tubes did not interfere with the function of young, normal swallowing mechanisms, as no subject aspirated with the 'tube-in' conditions, and pharyngeal clearance was complete in all the swallows. This suggests that the young, normal swallowing mechanism is able to functionally compensate for the invasive nature of the nasogastric tube. Similar observations were made by Robbins et al. (1992) regarding the effect of a manometric tube on swallowing function. Additional work to elucidate whether this finding is consistent for subjects in different age groups or those with dysphagia, is necessary.

An important issue is that young people with normal swallowing mechanisms were used as subjects in this study. If these durational swallowing changes caused by the wide-bore nasogastric tubes occur in **young normal** adults, what effect do the wide-bore tubes have on older individuals or those with dysphagia? It seems likely that wide-bore nasogastric tubes would have an even more debilitating effect on swallowing function in these subject populations, and even fine-bore nasogastric tubes may detrimentally effect swallowing in these groups. Future studies should aim to investigate these issues to provide a greater understanding of the effects of nasogastric tubes on the dysphagic swallowing mechanism.

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PERSONAL COMMUNICATION

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APPENDIX A

SUBJECT INFORMATION SHEET

STUDY AIMS:

To investigate the effects of nasogastric tubes on the normal swallowing mechanism.

PROCEDURES:

Each volunteer will be required to swallow 2 x 5 ml amounts of undiluted barium (a radio-opaque substance) under three experimental conditions i.e.

Condition 1 - no tube
Condition 2 - fine-bore nasogastric tube (8mm circumference)
Condition 3 - wide-bore nasogastric tube (16mm circumference)

Each of the 6 swallows will be observed using dynamic X -ray imaging (Fluoroscopy) and recorded on video cassette. Each study will take approximately 10 to 15 minutes to complete. A consultant radiologist and speech pathologist will be instrumental in collecting the data. Data will be analyzed in time measurements.

TUBE PLACEMENT:

Nasogastric tubes will be placed through the nose to the level of the upper oesophagus. Positioning the tubes will take place under radiological guidance to ensure correct placement. Nasogastric tube placement is an invasive procedure involving minimal risk of nasal or pharyngeal tissue damage. Discomfort may be experienced during tube placement.

RADIATION EXPOSURE:

The maximum fluoroscopy dosage will be equivalent to 336 milliroentgens for an exposure period of 15 minutes.

- Subjects may decline to participate in the study without giving reasons for withdraw

- Subjects are free to withdraw at any stage

- All information obtained will be confidential

- Should further information regarding the study be required, please contact Pippa Clarkson at 404-6458/66 or page 404-3333 (bleep 0570)

APPENDIX B

CONSENT FORM

Title: The effects of nasogastric tubes on the normal swallowing mechanism

Researcher: Phillipa Clarkson

(Please complete the whole form) Cross out as necessary

Do you understand the implications of your involvement?	YES/NO
Have you read the Subject Information Sheet?	YES/NO
Have you had an opportunity to ask questions and discuss the study?	YES/NO
Have you received satisfactory answers to all your questions?	YES/NO
Have you received enough information about the study?	YES/NO
To whom have you spoken?	
Do you understand that you are free to withdraw from the study:	
* at any time	YES/NO
* without having to give a reason	YES/NO
Do you agree to take part in this study?	YES/NO

Subject..

Signed..

APPENDIX C

DURATIONAL MEASURES

The ramus of the mandible was used as an anatomical reference for the division between the oral and pharyngeal cavities (Robbins et al., 1992). All the measures utilized have been described and used by Robbins et al. (1992) and Rosenbek et al. (1991).

1) Duration of maximal velar elevation (DOVE) -DOVE was calculated from the moment the maximal elevatory range of the velum was achieved (Figure 1), to the moment the maximal range was released (Figure 2).

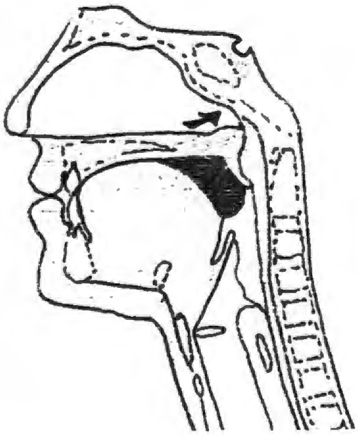

Figure 1

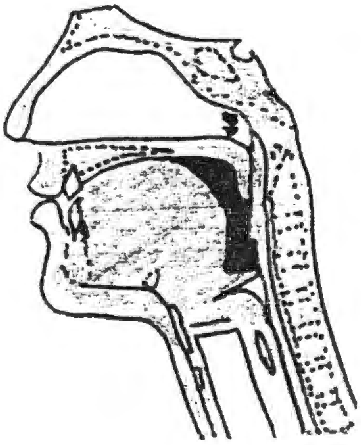

Figure 2

2) Duration of Stage Transition (DST) - DST was measured from the moment the bolus head passed the mandibular ramus (Figure 3) until maximal hyoid excursion was initiated (Figure 4).

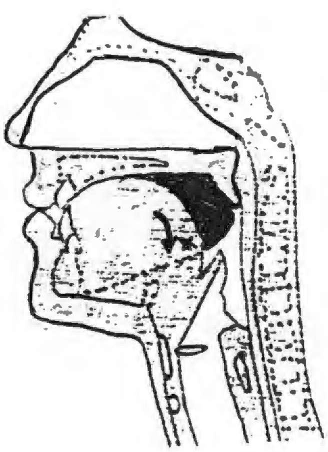

Figure 3

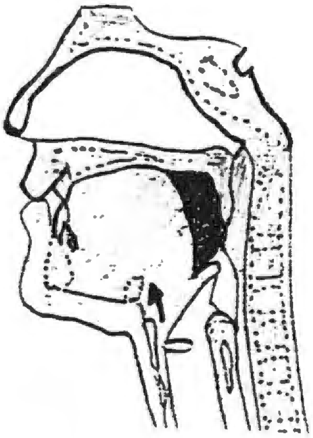

Figure 4

3) Duration of Pharyngeal Response (DPR) -DPR was measured from the initiation of maximal hyoid excursion (Figure 5) until the time the hyoid returned to rest (Figure 6).

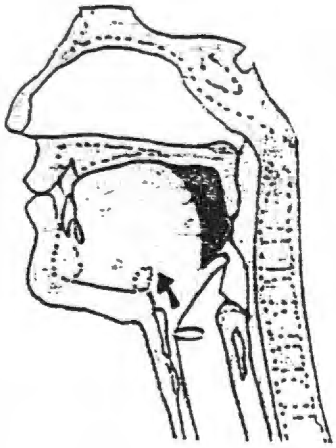

Figure 5

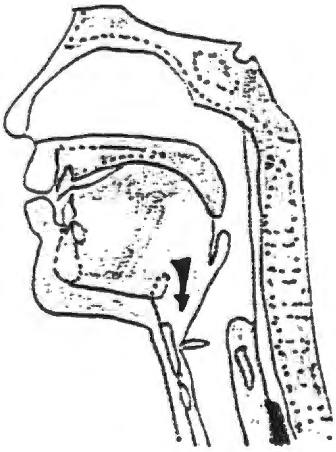

Figure 6

4) Duration of Pharyngeal Transit (DPT) -DPT was measured from the time the bolus head arrived at the ramus of the mandible (Figure 7) to the time the bolus tail passed through the upper oesophageal sphincter (Figure 8).

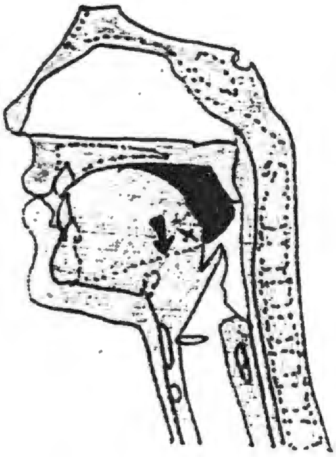

Figure 7

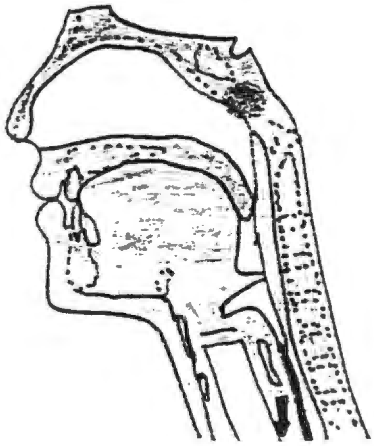

Figure 8

5) Duration of Upper Oesophageal Sphincter Opening (DUOSO) -DUOSO was measured from the first moment at which opening of the upper oesophageal sphincter was seen (Figure 9), until the time that the upper oesophageal sphincter closed (Figure 10).

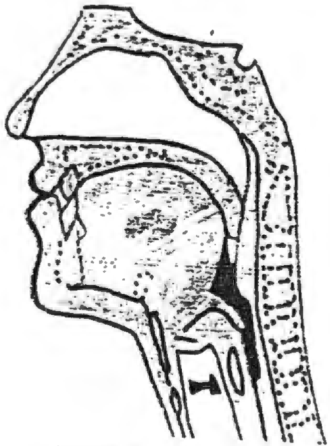

Figure 9

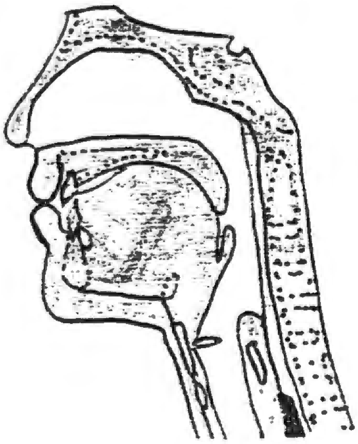

Figure 10

APPENDIX D

The following three non-temporal measures were analyzed.

1) Adequacy of bolus containment - this was demonstrated by the presence or absence of premature leakage of barium from the mouth into the pharynx (Figure 11).

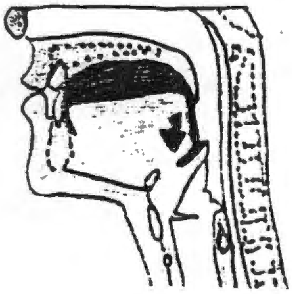

Figure 11

2) Adequacy of pharyngeal clearance - this was demonstrated by the presence or absence of residue in the vallecular space and the pyriform sinuses (Figure 12).

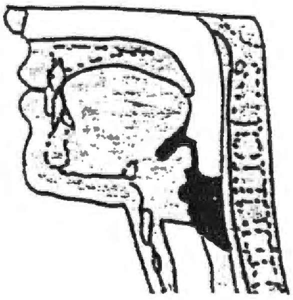

Figure 12

3) Adequacy of airway protection - this was demonstrated by the presence or absence of any laryngeal penetration (Figure 13) or aspiration (Figure 14).

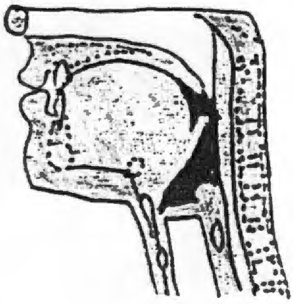

Figure 13

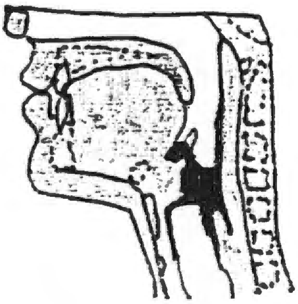

Figure 14