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This work and its defense approved by:

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EPISODES OF SpO2 DESATURATION AND ASPIRATION DURING VIDEOFLUOROSCOPY

A Thesis

Submitted to the Faculty of the University of Cincinnati in partial fulfillment of the requirements for the degree of Master of Arts

Department of Communication Sciences and Disorders

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By

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ABSTRACT

The relationship of SpO2 desaturation as measured by pulse oximetry with episodes of aspiration as documented by videofluorscopy (VFSS) was examined. Degree and length of desaturation were also examined. Relationships between SpO2 desaturation and demographic variables of gender, age and etiology of dysphagia were investigated. Data were collected from 36 subjects who underwent a videofluroscopic swallow study with simultaneous SpO2 monitoring by pulse oximetry. Thirty-one of the 36 subjects demonstrated laryngeal penetration or aspiration. Four of the 31 also demonstrated a significant SpO2 desaturation (4% or more). One subject showed SpO2 desaturation without episodes of laryngeal penetration or aspiration and one subject desaturated before episodes of laryngeal penetration/aspiration. Pulse oximetry alone would have failed to detect 27 of the 31 subjects who demonstrated laryngeal penetration/aspiration without the simultaneous VFSS. Oxygen saturation as monitored by pulse oximetry was significantly less reliable in detecting laryngeal penetration/aspiration than would be expected by chance (or by 50%).

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CHAPTER 1

Introduction

Chapter Summary

In this chapter, the bedside swallowing evaluation and the videofluoroscopic swallow study are presented as current assessment procedures for the evaluation of swallowing function. An introduction to pulse oximetry as an adjunct to swallowing evaluation is provided. The purpose of the study is identified. Research questions are asked and the null hypothesis stated.

Swallowing difficulties are a reality for many people of varying age, race, and gender. Causes of swallowing impairment include stroke, various neurological diseases, traumatic brain injury, chronic and obstructive pulmonary disease, side effects of certain prescription drugs and many more (Roseberry-Mckibbin & Hegde, 2000). Sometimes these difficulties resolve after recovery from an injury, but sometimes the individual must learn to compensate for the swallowing disorder by altering his/her diet, or under more severe circumstances, omitting oral food and liquid intake. These precautions are taken to prevent pneumonia caused by aspiration.

Aspiration is defined as the entry of secretions, fluids, food, or any foreign substance into the airway (Golper, 1998). Difficulty swallowing is a primary concern of healthcare professionals when evaluating whether a dysphagic individual should eat by mouth. Reliable assessment is vital in order to assure pulmonary functioning remains uncompromised with oral feeds. In the normal care of an individual with dysphagia, a bedside swallowing evaluation is typically the first type of assessment and is usually performed by the speech-language pathologist (SLP). It is often followed up with a videofluoroscopic swallow study (VFSS). Bedside swallowing evaluations are subjective and may be interpreted differently by SLPs, depending on levels of experience. They tend to over-diagnose aspiration (Smith, Lee, O'Neil & Connolly, 2000), but have been shown to miss up to 40% of silent aspirators (Lim et al., 2001). The bedside swallowing evaluation may more clearly identify patients who do not aspirate than those who do; therefore a VFSS is frequently ordered to provide additional information (Sherman, Nisenboum, Jesberger, Morrow & Jesberger, 1999). Videofluoroscopic swallow study is a radiographic assessment of dynamic swallowing function. It is a collaborative examination conducted by an SLP and radiologist. This procedure has been widely recognized as a reliable assessment tool, but its use in screening for aspiration is not always practical (Lim et al.), as it frequently cannot be performed at the bedside (Exley, 2000).

Alternatives or adjunct procedures have been sought to assist in the evaluation of swallowing. Accurate identification of aspiration in particular has been the focus. A limited number of studies have evaluated the use of pulse oximetry to detect aspiration in dysphagic individuals at the bedside. Of these studies, several endorse the use of pulse oximetry in evaluating dysphagia (Sherman et al., 1999; Collins & Bakheit, 1997), as a screening tool for risk of aspiration (Lim et al., 2001, Smith et al., 2000), and/ or as a monitor of progress during oral feeding (Rogers, Arvedson, Msall & Demerath, 1993). Others suggest that pulse oximetry is suitable only for assisting in the discrimination between dysphagic and nondysphagic individuals, but it should not be used as a diagnostic tool to assess the nature of dysphagia or identify aspiration (Colocny, 2000, 2001, Sellars et al., 1998, Dunnet & Carter, 1998).

The literature on the role of pulse oximetry in detecting aspiration is limited. Many of the studies are flawed by inadequate sample size or failure to use instrumentation simultaneously with pulse oximetry (Colodny, 2000). More research needs to be conducted in order to examine the effects of dysphagia and aspiration on oxygen saturation levels in the blood (SpO2) and consequently the efficacy of pulse oximetry in the assessment and management of dysphagic individuals.

Purpose of the Study

The purpose of the present study was to examine the relationship of SpO2 desaturation as measured by pulse oximetry with episodes of aspiration as documented by VFSS. This is one step in a series of studies that will need to be conducted in order to establish whether pulse oximetry is a reliable indicator of aspiration at the bedside.

Research Questions

This research study was designed to answer the following research questions:

1. Do episodes of SpO2 desaturation occur during liquid aspiration/penetration in individuals with dysphagia?
2. What is the degree (or change from baseline) of desaturation during episodes of liquid aspiration?
3. What is the length of desaturation episodes during/after liquid aspiration?

4. What is the relationship between the presence of SpO2 desaturation and etiology of dysphagia?
5. What is the relationship between degree of desaturation and etiology of dysphagia?
6. What is the relationship between length of desaturation and etiology of dysphagia?

Null Hypothesis

There will be no difference in the measured frequency of SpO2 desaturation during liquid aspiration from 50% chance.

Organization of the Study

Chapter I presents an introduction to the topic, statement of the problem, purpose of the study, research questions and null hypothesis. Chapter II provides a review of the literature on the normal adult swallow, dysphagia, respiration, coordination of respiration and swallowing, ventilation, pulse oximetry and its use as an adjunct to clinical swallowing evaluation. In Chapter III the methods and procedures of the study are presented. The results of the study are provided in Chapter IV and the conclusion is discussed in Chapter V.

CHAPTER II

Review of the Literature

Chapter Summary

In this chapter, the literature on the use of pulse oximetry as a diagnostic tool for evaluation of dysphagic individuals is reviewed. In addition, background information is given in the areas of the normal adult swallow, dysphagia, respiration, the coordination between respiration and swallowing, ventilation and pulse oximetry.

Normal Swallowing Function in Adults

During the normal adult swallow, a sequence of coordinated events occurs that ensures food and liquid are cleared from the oral cavity and the airway is protected. Each of these events must be present for a safe and effective swallow; however there is normal variation in the timing during which they occur (Logemann, 1998).

The stages of the normal adult swallow are the oral preparatory phase, oral phase, pharyngeal phase, and esophageal phase. The oral preparatory phase begins when the food or drink is first presented into the oral cavity. The material is then chewed if necessary, and manipulated into a bolus. The duration of this process depends on the taste, temperature, viscosity, and size of the bolus (Perlman, 2000). In order to effectively prepare the material for the swallow, one must consider the integrity of lip closure to seal the material in the oral cavity, velar movement for nasal breathing, tongue control for manipulation of the bolus, structures used in mastication, and sensory receptors throughout the oral cavity (Logemann, 1998). Additional factors that may affect this phase of the swallow are the degree of oral sensitivity, rate of secretion of saliva, viscosity of saliva, and dentition (Perlman).

During the oral phase of the swallow, the tongue begins to move the bolus posteriorly. The movement of the tongue during this process is a complex "anterior to posterior rolling action of the midline of the tongue, with tongue elevation progressing more posteriorly to push the bolus backward" (Logemann, 1998, pg. 27). It is often described as a 'stripping action' against the hard palate (Perlman, 2000; Logemann, 1998). This process typically takes less than 1 to 1.5 seconds to complete. The bolus is propelled to the oropharynx by the tongue which triggers the pharyngeal phase of the swallow (Logemann, 1998). Thicker consistencies require greater muscle activity for propulsion (Dantas & Dodds, 1990).

During the pharyngeal phase, the velum is elevated and retracted to completely close the velopharyngeal port, preventing nasal regurgitation. The hyoid and larynx elevate and move anteriorly to assist in airway closure as well as open the upper esophageal sphincter. For airway protection, the larynx closes at the levels of the true vocal folds, false vocal folds and epiglottis, creating a period of apnea which is usually followed by expiration. The cricopharyngeal sphincter opens to allow food or liquid to pass from the pharynx to the esophagus as the pharyngeal constrictors progressively constrict from the top to the bottom of the esophagus to move the food or liquid downward. This phase typically takes less than 1 second to complete (Logemann, 1998; Perlman, 2000).

The esophageal phase of the swallow begins where the bolus enters the esophagus at the upper esophageal sphincter until it passes into the stomach at the lower esophageal sphincter. This process typically takes anywhere from 8 to 20 seconds.. Esophageal disorders are typically identified and treated by a gastroenterologist (Logemann, 1998).

Dysphagia

Arvedson and Brodsky (2002, pg. 612) define dysphagia as "impaired swallowing, secondary to dysfunction in oral, pharyngeal, and/or esophageal phase, i.e., anywhere from the mouth to the stomach." Speech-language pathologists are concerned primarily with impairments in the oral cavity, pharynx, or larynx (Perlman, 2002), or oropharyngeal dysphagia. Symptoms of oropharyngeal dysphagia include aspiration, or the entry of food or liquid into the airway below the true vocal folds; penetration, or entry of food or liquid into the larynx at some level down to but not below the vocal folds; residue, or food that is left behind in the mouth or pharynx after the swallow; or backflow of food from the esophagus into the pharynx and/or from the pharynx into the nasal cavity (Logemann, 1998).

A greater number of elderly are experiencing swallowing disorders because of the increase in life expectancy and the incidence of acute and chronic ailments (Lugger, 1994). Seventy-five percent of strokes occur in individuals over the age of 65 and the incidence of stroke rises with age (Jones & Donner, 1988). According to recent studies, up to one-half of patients who have sustained an acute stroke have evidence of aspiration (Ding & Logemann, 2000; Yamaya, Yanai, Ohrui, Arai & Sasaki, 2001). Swallowing disorders may affect 10% of acutely hospitalized elderly, 30-60% of nursing home patients and up to 10% of individuals over the age of 50 (Hudson, Daubert & Mills, 2000).

Extensive study has shown that age-related alterations in swallowing, such as decreased salivary flow (Logemann, 1990), increased motor response time (Hudson et al., 2000) and decreased sensory capacity in the laryngopharynx (Aviv et al., 1994), can contribute to dysphagia. Other etiologies of oropharyngeal dysphagia include central nervous system dysfunction, as seen in stroke and Parkinson's disease; neuromuscular disorders, such as myasthenia gravis; and local structural lesions, seen with cancer and Zenker's diverticulum (Logemann, 1990).

Aspiration pneumonia can be a severe and potentially life threatening diagnosis. There are no distinctive features to this particular type of pneumonia except predisposition to aspiration (Ding & Logemann, 2000). Aspiration pneumonia can be caused by the aspiration of food, liquid, oropharyngeal and/or gastric secretions. The loss of protective swallowing and cough reflexes is thought to be one of the major risk factors for aspiration pneumonia (Yamaya et al., 2001), which is a cause for concern in dysphagic individuals.

Respiration

The respiratory cycle differs depending on the function of the airflow. When a person is sitting quietly, without an increased demand for air, the pattern used is known as quiet breathing; when a person is talking, speech breathing; and exercising, forced breathing. For the purpose of providing a brief overview of respiration, quiet breathing will be discussed. Alveolar pressure is the pressure within the lungs. Before the respiratory cycle begins, alveolar pressure is equal to atmospheric pressure or the pressure inside and outside of the lungs are the same. In order to initiate the inspiratory process, the diaphragm contracts downward, increasing the space inside the thoracic cavity and therefore decreasing the alveolar pressure. The pressure inside the lungs is now less than the pressure outside of the lungs. Because air moves from areas of high pressure to areas of low pressure, there will be an influx of air into the lungs in order to make the pressures equal again. This portion of the respiratory cycle is called inhalation. When the diaphragm relaxes and moves back to its tonic state, it decreases the area within the thoracic cavity, thus increasing the alveolar pressure. As a result, air will move from high to low pressure and rush out of the lungs until the atmospheric and alveolar pressures are equal once again. This phase of the cycle is known as exhalation (Dikeman & Kazandjian, 2003; Kent 1997).

Coordination of Respiration and Swallowing

Just as there are variations in the timing of events that occur during the normal adult swallow, there are also variations in the coordination of respiration with these events (Tarrant, Ellis, Flack & Selley, 1997). The most common pattern between respiration and normal swallowing occurs when the period of apnea, or cessation of breathing, interrupts exhalation (Logemann, 1998; Perlman, 2000; Dikeman & Kazandjian, 2003). In this instance, the swallowing sequence would be: "inspiration, expiration, initiation of a pharyngeal swallow, onset of an apneic interval, passage of the bolus, and then resumption of the same expiratory breath" (Dikeman & Kazandjian, pg. 272). It has been hypothesized that this pattern is safer than when the swallow interrupts inhalation because the air that flows through the larynx and pharynx during exhalation after the swallow may help to clear any residual material from around the airway entrance (Logemann, 1998; Dikeman & Kazandjian). Conversely, if the air is inhaled directly after the swallow, residue from around the airway entrance may also be aspirated. Pickersgill, Dawson, and Wiles (1998) found that 18.9% of apneic intervals in 20 patients with brain, spinal cord, and peripheral neurological lesions were followed by inspiration, an uncommon pattern in the normal population. A current area of interest is whether a particular respiratory-swallowing pattern is more common among people who aspirate versus people who do not aspirate (Perlman).

Variations in the most common respiratory-swallowing pattern may also affect the integrity of the swallow. For example, if the apneic interval is too short, the individual may inhale before the bolus is safely cleared from the pharynx (Dikeman & Kazandjian, 2003). Nishino, Yonezawa & Honda (1985) reported that the later a swallow occurred in expiration, the longer the expiratory phase. In this case, the dysphagic individual may exaggerate the pattern, or exhale even longer, in order to clear a bolus retained in the pharynx (Martin, Logemann, Shaker& Dodds, 1994). A study by Hiss, Treole & Stuart (2001) found that the swallowing apneic duration, or the length of the apneic interval during a swallow, increased with age. In other words, elderly adults had a longer apneic interval during swallowing than did young adults. This is consistent with a study by Sonies, Parent, Morrish & Baum (1988) which reported slower elderly adult swallows compared with young adult swallows. Hiss et al. (2001) also reported that the swallowing apneic interval of individuals also increased with increasing bolus volume. Females tended to have longer swallowing apneic intervals than did males (Hiss et al.).

Nilsson, Elberg, Bulow & Hindfelt (1997) documented that a longer period of apnea combined with a shorter pharyngeal transit time protects against laryngeal penetration in stroke patients. They also found that in those individuals who did have laryngeal penetration, the ratio between the apneic duration and the pharyngeal transit time was lower.

Respiratory patterns may differ for successive swallows because they require the individuals to hold their breath for a longer period of time. The apneic period lasts for the duration of the swallows, with expiration beginning after the last swallow (Dikeman & Kazandjian, 2003). Individuals with limited pulmonary endurance and reserves may experience difficulty holding their breath for multiple consecutive swallows and attempt to interrupt the swallowing sequence to inhale, thus causing them to be at a greater risk for aspiration (Martin et al., 1994).

Ventilation

The following description of ventilation is well described by numerous authors in the field. Ventilation is the process of gas exchange in and out of the lungs. In order to further investigate this process, one must understand the relationship between ventilation and perfusion. The alveolar-capillary unit is where the gas exchange takes place in the lung. Oxygen is brought into the lung, specifically to the alveoli, and carbon dioxide is taken from it. This is the alveolar ventilation portion of the process. Perfusion is when the mixed venous blood from the pulmonary capillaries brings carbon dioxide into the lung and takes oxygen from the alveoli. This relationship between the ventilation of the alveoli and the perfusion of the pulmonary capillaries determines the amount of oxygen saturation in the blood. If the ratio of ventilation to perfusion decreases, the removal of oxygen relative to its delivery will increase and the delivery of carbon dioxide relative to its removal will increase, thereby increasing the carbon dioxide in the blood and decreasing the oxygen in the blood. (Levitzky, 2003; Kent 1997; Leff & Schumaker, 1993)

The aspiration of food or liquid causes the stimulation of laryngeal chemoreceptors and/or reflex bronchoconstriction in a normally functioning mechanism. The reduction of air flow to the occluded lung leads to ventilation-perfusion mismatch and oxygen desaturation of arterial blood (Collins & Bakheit, 1997; Sherman et al., 1999).

Pulse Oximetry

Oxygen desaturation can be monitored with pulse oximetry, during which red and infrared light is directed through a finger or toe (Colodny, 2000, 2001). "The pulsating arterioles in the path of the sensor cause a change in the amount of light detected by a photodiode detector. The oximeter sensor calculates the ratio of admitted red to infrared light within the pulse waveform to determine the oxygen saturation" (Colodny, 2000, pg. 69). This method of determining oxygen saturation relies on the absorption of electromagnetic energy with change in the percentage of oxygen bound to the hemoglobin molecule (Moyle, 2002). Pulse oximetry is non-invasive, inexpensive, and used in many healthcare settings. It is dynamic in that it provides a continuous reading of arterial oxygen saturation that trends up or down in response to physiologic changes

(Cysewska- Sobusiak, 1999). Pulse oximetry is widely used as a general indicator of pulmonary status.

Pulse oximeters are not calibrated before starting measurements and Cysewska-Sobusiak (1999, pg 124) notes that "serious problems are connected with the standardization of pulse oximeters by manufacturers." Electronic simulators are used by the manufacturers to test only the electronic system, but there is no test for the optical sensor under various situations. A study by Cysewska- Sobusiak (1999), during which pulse oximetry was used in conjunction with samples of hemolized blood drawn from the radial artery, lends support that a single pulse oximeter reading can sometimes give incorrect information about oxygenation status.

Use of Pulse Oximetry as an Adjunct to Clinical Swallowing Evaluation

Pulse oximetry, in combination with a bedside swallowing examination, has received recent attention as a possible alternative to VFSS. However, in reviewing the literature on this combined assessment, the need for better understanding of the relationship between SpO2 desaturation and aspiration of food and/or liquids is evident. Incomplete understanding of the relationship between SpO2 readings and presence, absence, or degree of aspiration can lead to serious, life threatening misinformation regarding safety of the patient's swallow.

Rogers, Arvedson et al. (1993) introduced the use of pulse oximetry to monitor the SpO2 levels of patients with severe to profound cerebral palsy and oropharyngeal dysphagia. Pulse oximetry readings were compared to VFSS for each of the five subjects in order to determine if SpO2 levels changed during moments of aspiration. Rodgers, Arvedson et al. noted that pulse oximetry proved helpful in the decision to discontinue oral feeding for two cases. In another study by Rodgers, Msall & Shucard (1993), desaturation was noted in three adults with severe neurological disabilities and dysphagia. However, neither of the studies performed pulse oximetry and VFSS simultaneously, which limits the interpretation of the results.

Of the studies that advocate pulse oximetry as a reliable method in the diagnosis of aspiration and/or management of the dysphagic individual, several proposed a combination of pulse oximetry with a bedside swallowing examination in order to give the best positive predictive value (Lim et al., 2001, Smith et al., 2000, Collins & Bakheit, 1997, Sherman et al., 1999). In a study by Smith et al., 53 subjects were screened using pulse oximetry followed immediately by a bedside swallowing assessment. The pulse oximetry alone failed to detect 14% of aspirators/penetrators. As a combined assessment, the study had a positive predictive value of 95%, or was able to detect aspiration in 95% of the aspirating subjects. According to these results, Smith et al. hypothesizes that only 5% of patients would be unnecessarily given nil by mouth. The results from a study by Lim et al. indicate that the combination of a 50ml water swallow test and the oxygen desaturation test gives a positive predictive value of 78.8% and a negative predictive value of 100%. In other words, 78.8% of the individuals who aspirate will fail the combination of the two tests, giving indication to the healthcare professional about the patient's risk for aspiration without actually undergoing an imaging study. Professionals will also be equipped to exclude the possibility of aspiration for 100% of the patients who do not aspirate, thus eliminating the risk of unnecessarily suspending oral feeds. A limitation of this study was that the water swallow and oxygen desaturation tests were not done simultaneously with imaging (Lim et al.). One must also consider the implications of the failure to detect the remaining 21.2% of aspirators by the combination of the 50ml water swallow test and the oxygen desaturation test.

Sherman et al. (1999) measured pulse oximetry concomitantly with VFSS and found that there was not only an association between SpO2 desaturation and swallowing abnormalities, but suggested there may be a direct relation between the degree of oxygen desaturation and the severity of the swallowing abnormality. In this study, the SpO2 levels of 46 individuals were monitored while they underwent a VFSS. The results indicated that even though the baseline SpO2 values were variable across the subjects, the patients who aspirated uniformly demonstrated desaturation below the lowest baseline value. There were also significant differences between the oxygen desaturation in patients with normal or minimal dysphagia as compared with those with a more pronounced pharyngeal phase dysphagia. These results indicate that pulse oximetry may be used to classify patients for further evaluation based on the degree of oxygen desaturation.

A study by Colodny (2001) examined the effects of age, gender, disease, and multisystem involvement on oxygen saturation levels of 104 dysphagic patients and 77 nondysphagic persons. Results from this study suggest that individuals with dysphagia may not desaturate while aspirating, implying that the premise underlying the efficacy of pulse oximetry in the detection of aspiration may be fallacious. The author attributes the lack of desaturation to the lower saturation levels prior to, during, and following oral feedings of the individuals who aspirate. In addition, neither gender nor multisystem involvement seemed to have an effect on SpO2 levels. Age only affected SpO2 levels when it was combined with an assault to the system, such as CVA or COPD. Another study by Colodny (2000), in which 104 dysphagic individuals were evaluated, lends additional support that SpO2 levels show no dramatic changes during or after swallowing or during episodes of aspiration. The author concluded that desaturation seemed to be more a function of dysphagia than of aspiration.

Leder (2000) studied 60 patients in the intensive care unit undergoing a FEES simultaneously with pulse oximetry. Results from the study indicated there were no significant differences in SpO2 levels based on aspiration status or requirements for supplemental oxygen. Leder concluded that change in SpO2, heart rate, or blood pressure values as markers of aspiration was not supported.

A study by Sellars et al. (1998), which included 6 dysphagic subjects and 5 normal subjects, also found that there was no clear-cut relationship between changes in arterial oxygenation and aspiration. The authors caution against the use of pulse oximetry as a clinical tool to detect aspiration. An obvious limitation of this study was the small number of subjects, but it raised questions about previous research supporting the use of pulse oximetry for the detection of aspiration based on the association with SpO2 desaturation (Colodny, 2000).

Purpose of the present investigation

Pulse oximetry proves to be valuable in the healthcare setting; however its use in detecting aspiration is still controversial. The idea of using a non-invasive, clinical tool at the bedside which gives objective information about the integrity of an individual's swallow is hopeful. The numerous benefits range from decreasing the number of costly imaging studies to monitoring an individual's progress during treatment. It is imperative, however, that there is understanding of the technology in which professionals are placing their confidence and the faith of their patients. There is conflicting information in the literature on the use of pulse oximetry in detecting aspiration. Many of the research studies were not done simultaneously with an imaging study, and therefore lack solid evidence that the desaturation episodes were truly coordinated around aspiration or laryngeal penetration. Continued evaluation of the efficacy of pulse oximetry as a diagnostic tool in detecting aspiration and/or laryngeal penetration is necessary in order to ensure safe and ethical practices when evaluating and treating individuals with dysphagia.

CHAPTER III

Methods

Chapter Summary

Chapter III outlines the subjects, materials, procedures, and data analysis of the study. The sample size of 36 subjects is stated. Baseline data were collected for up to 10 minutes prior to the study and posttest data were collected for up to 5 minutes following the study. For each patient, the medical chart was reviewed in order to obtain the age, gender, diagnosis and past medical history.

Subjects

Thirty-six subjects who had been referred for a standard videofluoroscopic swallow study (VFSS) at Jewish Hospital, Cincinnati, Ohio were recruited to participate in this study; 18 males and 18 females. The age range was from 40-98 years with the mean age of 77 and the majority (15) between the ages of 81-90. The etiologies of dysphagia for each of the subjects were classified as either neurological, pulmonary, cardiopulmonary, gastrointestinal, dementia, head/neck cancer or 'medical other' (see Appendix I). Eight of the subjects were on supplemental oxygen at the time of the study. Prior to participation, all potential subjects completed a consent form. Consent was obtained from the Power of Attorney or next of kin when the patient was unable to provide informed consent

Materials

A Nonin 8500 digital pulse oximeter was used to monitor SpO2 levels. The VFSS was recorded according to standard procedure. The readings from the SpO2 were recorded on the data collection form. A video recorder was used to videotape the pulse oximetry readings as well as the voice of the SLP noting each episode of aspiration or penetration.

Procedures

1. The patient had a Nonin 8500 digital pulse oximeter probe placed on his/her finger throughout the study to monitor the SpO2 levels.
2. A baseline SpO2 reading was taken for 10 minutes prior to the VFSS with readings every minute, continuous readings for the duration of the study, and 5 minutes following completion of the exam with minute readings.
3. The VFSS proceeded per standard clinical practice with the addition of simultaneous/ continuous SpO2 monitoring. The participating SLP (PI) observed any aspiration, laryngeal penetration, or other abnormal swallowing events during the VFSS.
4. Any abnormal swallowing events were verbally marked by the participating SLP. Simultaneous SpO2 monitoring was conducted by the graduate student co-investigator who recorded SpO2 values during each laryngeal penetration/aspiration episode. Timing of SpO2 fluctuations (around swallow events) and duration of desaturation episodes, if they occurred, was recorded

by the graduate student researcher. To ensure timing of events (desaturation and swallowing) were truly coordinated, the pulse oximeter display was video-recorded with simultaneous audio recording of the SLP's voice.

5. In the event abnormal swallow events such as aspiration occurred, continuation of the study was determined by the clinical judgment of the attending radiologist and SLP.

Data Analysis

The data were entered into an Excel spreadsheet according to the consistency and manner of presentation and the corresponding SpO2 value for each subject. The dichotomous data were analyzed using a basic chi-square analysis at $x^2 \leq .005$. The other data were presented using qualitative analysis.

CHAPTER IV

Results

Presence of SpO2 desaturation and aspiration/penetration

To determine if episodes of SpO2 desaturation occur during liquid aspiration in dysphagic individuals, episodes of desatuation timed with aspiration or laryngeal penetration were tabulated for all subjects and are presented in Table 1. In all, 31 of the 36 individuals (86%) demonstrated some degree of penetration or aspiration. Only four of the 31 individuals (13%) who penetrated and/or aspirated showed SpO2 desaturation during/after the episode. To examine whether measurement of desaturation had any reliable relationship with episodes of penetration/ aspiration, those data were analyzed using a basic chi-square analysis at $x^2 \leq .005$. When the number of subjects who penetrated and desaturated (n = 1) or aspirated and desaturated (n = 3) and the number who penetrated/aspirated, but did not desaturate (n = 27) were compared with that expected by chance, (half desaturating and half not desaturating), the value obtained was 9.89. The critical value at 1df is 7.9. Therefore, the stated null hypothesis, *There will be no difference in the measured frequency of SpO2 desaturation during liquid aspiration from 50% chance*, was accepted. That is, the reliability of pulse oximetry in detecting aspiration or penetration was significantly worse than would be expected by chance (or 50%).

Degree of SpO2 desaturation

For those subjects whose SpO2 levels did desaturate, the degree of desaturation is outlined in tables 2.1 and 2.2. Four values were given for each subject; the minimum baseline value, or the lowest value obtained before the videofluoroscopic procedure began; the mean baseline value, or the average baseline value obtained before the videofluoroscopic procedure began; the change from the minimum baseline value, or the degree of desaturation from the lowest pretest value; and the change from the mean baseline value, or the degree of desaturation from the average baseline value. As outlined in table 2.1, only four of the 31 subjects (13%) who penetrated or aspirated showed a significant degree (or at least a four point drop) of SpO2 desaturation.

Table 1: Occurrence of Penetration/Aspiration and Desaturation Episodes

Subject	# of penetration episodes	Desaturation after a penetration episode	# of aspiration episodes	Desaturation after an aspiration episode	Desat. before episodes of pen/asp	Desat. uncertain to specific episode of pen/asp	Desat. with no episodes of pen/asp
A	5	No	0				
B	1	No	2	No			
C	4	No	0				
D	1	No	0				
E	1	No	2	No			
F	0		1	No			
G	4	No	0				
H	2	No	0				
I	3	No	0				
J	0		2	No	Yes		
K	1	No	1	No			
L	1	Yes	2	No			
M	1	No	1	No			
N	1	No	1	No			
O	0		0				
P	0		2	No			
Q	3	No	0				
R	1	No	0				
S	0		0				
T	0		2	No			
U	10	No	0				
V	1	No	1	No			
W	0		1	No			
X	0		0				
Y	1	No	0				
Z	2	No	0				
AA	1	No	1	No			
BB	2	No	0				
CC	4	No	3	No			
DD	4	No	1	Yes			
EE	5	uncertain	3	uncertain		Yes	
FF	1	No	0				
GG	1	No	0				
HH	0		0				
II	0		3	Yes			
JJ	0		0				Yes

For subject EE, the desaturation occurred throughout the penetration and aspiration episodes. Therefore it was difficult to determine if the desaturation occurred as a result of a specific episode.

Table 2.1: Degree of Desaturation for Four Subjects Demonstrating Both Penetration and Aspiration

Subject	Lowest baseline SpO2 value	Mean baseline SpO2 value	1st desaturation episode-change from lowest value	1st desaturation episode-change from mean baseline	2nd desaturation episode-change from lowest value	2nd desaturation episode-change from mean baseline
L	97%	97.9%	-6 (91% SpO2)	-6.9 (91%SpO2)		
DD	92%	93.8%	-4 (88% SpO2)	-5.8 (88% SpO2)		
EE	92%	93.6%	-14 (78% SpO2)	-15.6 (78% SpO2)	-8 (84% SpO2)	-9.6 (84% SpO2)
II	95%	97%	-6 (89% SpO2)	-8 (89% SpO2)		

Table 2.2: Degree of Desaturation in two Subjects who did not demonstrate Penetration or Aspiration

Subject	Lowest baseline SpO2 value	Mean baseline SpO2 value	1st from minimum baseline	1st from mean baseline
J	93%	96.4%	-9 (84% SpO2)	-12.4 (84% SpO2)
JJ	93%	94.4%	-4 (89% SpO2)	-5.4 (89% SpO2)

<u>Length of desaturation</u>

Tables 3.1 and 3.2 show the length of the desaturation episodes for the four subjects who desaturated. Table 3.1 shows the length of desaturation for those subjects

whose desaturation occurred after laryngeal penetration or aspiration of liquids, ranging from 5 seconds to 3 minutes. The length of desaturation for the subjects who desaturated without an obvious link to penetration/aspiration is outlined in table 3.2. Due to the small number of subjects from the sample population who experienced SpO2 desaturation, no trends regarding length of desaturation were identified.

Table 3.1: Length of Desaturation associated with Penetration/Aspiration

Subject	Length of 1st desaturation episode
L (pen)	5 sec
EE (asp)	50 sec
DD (asp)	Fluctuated for up to 3 min. post. (penetration without clearing)
II (asp)	13 sec

Table 3.2: Length of Desaturation without association to Penetration/Aspiration

Subject	Length of 1st desaturation episode
J	84 sec continuously (1 episode/ 5 food trials)
JJ	2 sec

Presence of desaturation and etiology of dysphagia

Tables 4.1 and 4.2 denote the presence of desaturation episodes and the subjects' etiology of dysphagia. The etiologies of dysphagia for those subjects who desaturated as a possible result of penetration or aspiration were of neurological and pulmonary origin. Both of the subjects who desaturated either before episodes of laryngeal penetration/aspiration or with no episodes of penetration/aspiration had cardiopulmonary etiologies of dysphagia. Again, Table 4.1 shows the desaturation episodes which may have occurred as a result of penetration or aspiration and 4.2 shows the subjects who desaturated without association to laryngeal penetration/aspiration.

Table 4.1: Desaturation and etiology of dysphagia

Subject	Etiology of dysphagia
L	Neurological
EE	Pulmonary
DD	Neurological
II	Neurological

Table 4.2: Desaturation not associated with pen/asp and etiology of dysphagia

Subject	Etiology of dysphagia
J	Cardiopulmonary
JJ	Cardiopulmonary

Table 5 outlines the etiologies and number of penetration and aspiration episodes for each of the subjects who did not experience SpO2 desaturation.

Table 5: Subjects who aspirated or penetrated without SpO2 desaturation

Subject	Aspirated	Penetrated	Etiology
A	5		Cardiopulmonary
B	2	1	Head/Neck CA
C		4	GI
D		1	COPD
E	2	1	Medical Other
F	1		Neurological, Dementia
G		4	COPD
H		2	COPD
I		3	Neurological
K	1	1	COPD
M	1	1	COPD
N	1	1	Neurological
P	2		Cardiopulmonary
Q		3	GI
R		1	COPD
T	2		Neurological, Medical Other
U		10	Neurological
V	1	1	Cardiopulmonary
W	1		Pulmonary, Neurological
Y		1	Medical Other
Z		2	Neurological
AA	1	1	Neurological
BB		2	Neurological
CC	3	4	Neurological
FF		1	COPD
GG		1	COPD

CHAPTER V

Discussion

Chapter Summary

The results of the study are analyzed and the research questions discussed. The findings of this study are compared to the findings of previous literature on the use of pulse oximetry as an adjunct to clinical swallowing evaluation. The limitations of the study are presented and the clinical significance and conclusion stated.

To determine if a clinically and or statistically significant relationship existed between laryngeal penetration and aspiration during liquid swallows in dysphagic individuals, videofluoroscopic swallow studies were performed concomitantly with oxygen saturation monitoring by pulse oximetry.

Question #1-*To answer the first question regarding episodes of SpO2 desaturation that occur during liquid aspiration in individuals with dysphagia,* the data were first examined using descriptive statistics. A tabulation of the raw data revealed that 31 of the 36 subjects (86%) revealed single or multiple episodes of laryngeal penetration and/or aspiration, but only four of those subjects demonstrated both episodes of aspiration or laryngeal penetration and desaturation. Therefore, episodes of laryngeal penetration and aspiration were observed in a few subjects. To determine the relationship and reliability of pulse oximetry to detection of airway soiling and frank aspiration, a chi-square analysis was conducted. The reliability of pulse oximetry in detecting aspiration or penetration was significantly worse than would be expected by chance (or 50%). By using pulse oximetry exclusively, 27 of the 31 subjects (87%) would not have been identified as demonstrating aspiration or being at risk for aspiration because of laryngeal penetration based on their oxygen saturation levels. In addition, one of the subjects desaturated before aspirating or penetrating and one showed SpO2 desaturation with no episodes of aspiration or penetration. These results have very serious clinical implications and question the efficacy of using pulse oximetry to detect aspiration at the bedside.

The results from this study are consistent with those found by Leder (2000) and Sellers et al. (1998). There were no clear cut relationships between arterial oxygen saturation as measured by pulse oximetry and penetration or aspiration of liquids.

The findings from this study were inconsistent with those from Lim et al. (2001), Smith et al. (2000) and Collins & Bakheit (1997). The inconsistencies could be attributed to the fact that each of these studies considered a 2% decline in SpO2 to be significant. In addition, because SpO2 desaturation of 2% or more occurred with individuals from these studies, does not necessarily mean that the desaturation is a direct effect of aspiration. As Leder (2000) suggests, a change in posture after aspiration, coughing in an attempt to clear the aspirated material, and the swallowing apnea itself may play a role in the desaturation.

Question #2- The *degree (or change from baseline) of desaturation during episodes of liquid aspiration:* These data were analyzed by a number count of subjects who penetrated or aspirated and showed at least a 4% drop in SpO2. Based on literature reports and clinical practice, a 4% drop in SpO2 was the predetermined level of clinical significance used in the current study. Sellers et al. states that 4% variation is the internationally accepted criterion for an abnormal SpO2 decline. Other studies use a 2%

criterion (Lim et al., 2001; Smith et al., 2000; Collins & Bakheit, 1997; Higo, Tayama, Watanabe & Nito, 2003), however, a 2% fluctuation was frequently seen during baseline readings for this study. It was not uncommon for movement, or simply the act of a subject moving the cup to his/her mouth, to cause a subsequent SpO2 drop of 3% or less.

Only four of the 31 subjects who penetrated or aspirated showed a significant degree (or at least a four point drop) of SpO2 desaturation. Of the 27 subjects who aspirated or penetrated but did not show a significant SpO2 desaturation, 13 demonstrated episodes of aspiration; 21 showed episodes of penetration. From the 13 who aspirated, there were a total of 23 aspiration episodes that did not show subsequent SpO2 desaturation. From the subjects who demonstrated laryngeal penetration, there were 46 episodes that did not show a significant SpO2 decline. In total, 69 episodes of laryngeal penetration and aspiration would have gone undetected by using pulse oximetry alone. Were this test alone driving clinical decisions, those 27 subjects might not receive the most prudent advice regarding dietary management and airway protection strategies.

Question # 3- *Length of desaturation episodes during/after liquid aspiration:* The length of desaturation episodes were analyzed using the video recordings of the pulse oximeter for those subjects who demonstrated SpO2 desaturation. For each of the four subjects, the episodes were timed from the moment the SpO2 reached 4 points below the minimum baseline value until the SpO2 went back up to 3 points below the minimum baseline value. For example, if the minimum baseline value was 92%, the desaturation episode began at the moment the pulse oximeter displayed 88% or lower and continued until it went back up to 89%. The desaturation lengths for each of the four subjects were between 5 seconds and 3 minutes. Further analysis of the penetration/aspiration episodes, using the Rosenbeck's pen/asp scale, would give more information about the range of desaturation length for each of these subjects. For example, if a subject did not show frank aspiration, rather deep laryngeal penetration without clearing, SpO2 desaturation may be delayed (because of the eventual aspiration of the penetrated material) and the duration of the desaturation may be longer because of slow, delayed periods of aspiration after the initial swallow. However, analysis of each episode of laryngeal penetration per Rosenbeck's Pen/Asp scale was beyond the scope of this study.

Question #4- *The relationship between episodes and degree of desaturation and etiology of dysphagia*: When the etiologies of the entire sample were ranked according to the number of subjects with the etiology, the top three were neurological (14), pulmonary (9), and cardiopulmonary (5). For the 6 subjects who experienced SpO2 desaturation, each belonged to one of the top three etiological groups; neurological (3), pulmonary (1), and cardiopulmonary (2). Three of the six subjects who showed SpO2 desaturation were from the neurological group. However, 14 of the 39 etiologies from the entire sample were neurological. There were 39 diagnoses of etiology for 36 patients because some patients fell into more than one etiological group. Subjects from only the top three etiological groups desaturated; however, hypothesizing about the correlation between the etiology of dysphagia and the presence of desaturation episodes may be inaccurate due to the small number of subjects who actually desaturated. Therefore, the high percentage of the same etiologies of dysphagia for those subjects who desaturated might be a result of sampling rather than of clinical significance.

Questions # 5 and #6- *The relationships between degree and length of desaturation and etiology of dysphagia:* When comparing the etiologies of dysphagia with the degree and length of SpO2 desaturation for the subjects who desaturated, the same sampling problem persists. It is difficult to draw correlations when the subjects who desaturated were so few. A larger sample size may provide additional insight into etiology of dysphagia and the degree and length of SpO2 desaturation.

Similarly, the specific influence of age, gender and use of supplemental oxygen could not be determined based on the few number of subjects who demonstrated SpO2 desaturation.(see Appendix II for these data.)

Laryngeal penetration was included in this study in addition to aspiration because it is considered a predictor of aspiration. Although a direct relationship between physiological pulmonary changes (that would be detected by pulse oximetry) aren't clearly linked to laryngeal penetration, it may be possible that laryngeal chemoreceptors become stimulated resulting in a fluctuation of SpO2 readings. Also, deep laryngeal penetration that does not clear could eventually be aspirated. Either of these instances may link to episodes of SpO2 desaturation.

Clinical Significance

Accurate assessment procedures are vital in order to determine the safest and least restrictive diet for dysphagic individuals. The results of the study indicated that pulse oximetry was significantly worse at detecting aspiration and laryngeal penetration than would be expected by chance. The consequences of using oxygen saturation levels as an indicator of aspiration or laryngeal penetration without an imaging study such as VFSS or fiberoptic endoscopic evaluation of swallowing (FEES) could be life-threatening to the patient.

Limitations

The entire sample size was 36 subjects, but because only 6 of the subjects desaturated and only four desaturated as a possible result of penetration/aspiration, drawing conclusions based on their demographics and interpretation of the data are limited.

Another limitation to the study is due to the environment in which the data were collected. The videofluoroscopy procedure was conducted in the x-ray department at Jewish Hospital in Cincinnati, OH. As with many acute care hospitals, this department is used for multiple x-ray procedures and is therefore very busy. It was not always possible to collect 10 minutes of baseline data and five minutes of posttest data, as the study protocol outlined.

The space in which the study was carried out was very small. In addition to the speech-language pathologist, radiologist, graduate student researcher, and subject, it was also necessary to have room for a tripod holding the video recorder. As a result, some of the videotapes with data on the pulse oximetry readings are momentarily obstructed because of the SLPs arm while feeding the subject. The obstructions last no longer than three seconds. The pulse oximetry readings were recorded in real time by the graduate student researcher, so the presence of desaturation episodes were identified at that time, but further analysis of the videotapes for length of desaturation may be inaccurate by up to three seconds.

The pulse oximeter provided a stream of continuous readings that fluctuated up and down according to changes in the patients' arterial blood oxygen saturation. Seldom did the pulse oximeter show a constant value without fluctuations for longer than several seconds. While recording the readings after each swallow, the lowest SpO2 value in the fluctuation was taken.

The oxygen saturation differed between fingers in some patients. Respiratory therapists at Jewish hospital use a 'finger, thumb, thumb' procedure, whereby initially an index finger is checked for a 'reasonable' pulse oximeter reading. If the reading appears too low, then the thumb of the same hand is tested. If the reading still appears abnormal, then the thumb on the opposite hand is tested. The same protocol was used during this study. The reliability between digits on the same individual is another factor to consider when evaluating pulse oximetry as a clinical tool for dysphagia.

Conclusion

In conclusion, this study supports the literature which cautions against the use of pulse oximetry in evaluating an individual's swallow at the bedside if it is to be interpreted as a specific indicator of swallowing difficulties such as laryngeal penetration or aspiration (Leder, 2000; Sellers et al., 1998; Colodny, 2000, 2001). Future research with a larger sample population may provide additional information about the specific timing of the desaturation episodes with regard to laryngeal penetration and aspiration. Example research questions might include, 'What is the relationship between depth of laryngeal penetration and length of desaturation episode?' and 'What is the relationship between etiology of dysphagia and presence/length/degree of SpO2 desaturation?' Additional research in this area is necessary in order to better understand the relationship between aspiration and laryngeal penetration on SpO2 saturation levels and determine whether pulse oximetry has a place in the assessment of dysphagic individuals.

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Appendix I

Date of MBS	Subject	Gender	Age	Diagnosis	Past Medical History	Etiology of Dysphagia
3/11	A	Female	66	r/o MI	CAD, CHF, IDDM, GERD	Cardiopulmonary
3/12	B	Female	62	Left radical neck dissection	TAH, CA, Right radical neck dissection (11/02), fallopian tube CA	Head/Neck CA, Radical Neck Dissection
3/15	C	Female	81	Dysphagia	GI problems (2000)	GI
3/15	D	Female	92	Pneumonia	Breast CA, HTN, Bilat. knee replacement, COPD, idiopathic speech difficulty	COPD
3/15	E	Female	82	Syncopal episodes,	Sjogren Syndrome, A-Fib, HTN, CHF, CAD, osteoporosis, depression, pneumonia	Medical other Systemic
3/16	F	Male	83	Dysphagia	Dementia, Alzheimer's, COPD	Neurological Dementia
3/18	G**	Male	54	COPD exacerbation	COPD, respiratory failure, HTN, schizophrenia, CLL, seizure disorder, pneumonia, intubated 3/14-3/16	COPD
3/22	H	Female	89	Dysphagia	Recurrent LLL pneumonia, COPD, emphysema, pleural effusions, CRF	COPD

3/23	I	Male	67	Brain tumor	Dysphagia	Neurological
3/23	J	Male	90	CHF exacerbation	A-fib, AAA repair (1999), CHF, HTN	Cardiopulmonary
3/23	K	Male	84	Dysphagia	Emphysema, asthma, PVD	COPD
3/24	L	Female	84	Dysphagia	CVA, Parkinson's, dysphagia	Neurological
3/24	M**					
3/24	N	Male	82	Dysphagia	CVA, trach removed (12/03), prostate CA	Neurological
3/25	O	Female	77	GI bleed	HTN, Esophagitis, upper GI bleed, Nephrolithiasis, Dementia, dysphagia, s/p PEG, Hiatal Hernia, GERD, CAD	GI Dementia
3/25	P	Male	77	Dysphagia	Pneumonia, CHF, HTN, diabetes, pulmonary edema, Left BKA	Cardiopulmonary
3/29	Q	Male	61	Dysphagia	GERD, acid reflux	GI
3/29	R	Male	86	COPD exacerbation	Dementia, A-Fib, sacral decubitis with cellulitis	COPD
3/30	S	Male	78	UTI	CHF, CAD, CAF, end stage renal disease, seizure disorder, HTN, DM II, CVA, UTI, COPD	Medical Other
3/30	T	Male	83	Nausea, Vomiting, SOB	Dementia, depressive disorder, diverticular	Neurological Multiple Medical

					disease, insulin requiring diabetes, dysphagia, s/p PEG tube, GERD, chronic A-fib, CHF, COPD, MRSA, pneumonia	
4/01	U	Female	78	Dysphagia	CVA	Neurological
4/02	V	Female	82	Urosepsis	CHF, depression, high cholesterol, HTN, hypothyroidism, intubated 3/08-3/15	Cardiopulmonary
4/02	W	Male	66	Fever, pneumonia?	CVA (2001), Lung CA with metastasis, NIDDM, sycoma cell CA (1/04)	Pulmonary Neurological
4/02	X	Female	79	Seizure	Pancritits, DM II, GERD, depression, UTI, HTN, colon CA, CVA, seizure disorder	GI Neurological
4/02	Y	Male				Medical Other
4/02	Z	Female	89	Abdominal pain, A-Fib	HTN, breast CA, hypothyroidism	Neurological
4/05	AA	Female	89	CVA	CHF, A-Fib, HTN, Hypothyroidism, pneumonia	Neurological
4/05	BB	Female	81	Dysphagia	CVA (1999), GERD	Neurological
4/05	CC	Female	81	CVA	HTN	Neurological
4/07	DD	Female	50	Dysphagia	MS, nutral valve prolapse	Neurological
4/07	EE	Male	98	Acute pulmonary edema	Insignificant	Pulmonary
4/23	FF	Female	75	Dysphagia	COPD,	COPD

					depression, HTN, osteoporosis,	
4/26	GG	Female	86	COPD exacerbation	Breast CA, asthma	COPD
4/26	HH	Male	45	Dysphagia	MR, hyperthyroidism	Neurological
4/26	II	Male	93	CVA	Pneumonia, dementia, CABG, HTN, depression, CAD, bladder CA	Neurological
4/26	JJ	Male	77	s/p CABG	HTN, anemia, MI, LU dysfunction	Cardiopulmonary

Appendix II

Gender and age of subjects who desaturated

Subject	Gender	Age
L	Female	84
EE	Male	98
DD	Female	50
II	Male	93

Gender and age of subjects who desaturated with no association to episodes of penetraton/aspiration

Subject	Gender	Age
J	Male	90
JJ	Male	77

Appendix III

Presence of supplemental oxygen during the study for subjects who desaturated as a possible result of penetration/aspiration

Subject	Supplemental O2
L	Yes
EE	No
DD	No
II	No

Presence of supplemental oxygen during the study for subjects who desaturated without association with episodes of penetration/aspiration

Subject	Supplemental O2
J	Yes
JJ	Yes

Appendix IV

Consistency and Manner of Presentation during which Episodes of Desaturation, associated with Penetration/Aspiration Occurred

Subject	1st desaturation consistency	1st desaturation administration	2nd desaturation consistency	2nd desaturation administration
L	Honey	Cup		
EE	Honey	Cup	Honey	Cup
DD	Nectar	Teaspoon		
II	Puree	Teaspoon		

Consistency and Manner of Presentation during which Episodes of Desaturation not associated with Penetration/Aspiration Occurred

Subject	1st	2nd	3rd	4th	5th
J	Puree, Tsp.	Puree, Tsp.	Honey, Tsp.	Honey, Cup	Nectar, Tsp
JJ	Thin, Cup				

(Subject J's one episode of SpO2 desaturation continued throughout five liquid trials of different consistencies.)