DISCUSSION

The present study assessed the qualitative and quantitative measures of swallowing in normal adults. The obtained results are discussed under the following headings:

- Qualitative measures
- Quantitative measures
  - Surface EMG
  - Nasal airflow monitoring
  - Cervical auscultation

**Qualitative Measures:**

The aim of the study was to develop a swallowing assessment protocol for adults and geriatrics to identify the presence of dysphagia, to establish possible etiology for dysphagia in relation to anatomical and physiological basis of swallowing, assess the ability to identify aspiration, to determine the possibility for oral feeding, to make recommendations regarding the alternative feeding methods, and to determine the need for further instrumental evaluation. The developed protocol provides the qualitative information of sensory and motor skills related to swallowing and all the phases of swallowing except esophageal phase.

These tasks for the assessment were originally derived from a composite of standardized and non-standardized clinical assessments tools. A review of literature confirmed that the items included in this protocol sampled all the relevant clinical dimensions of acquired swallowing dysfunction. Comparison with the other clinical assessment tools (Linden, & Siebens, 1983; Vittali, 1986; Splaingard, et al., 1988; Horner & Massey, 1988; Splaingard, et al., 1988; Jelm, 1990; DePippo, et al., 1992; Hinds & Wiles, 1998; Horner, et al., 1993; Linden, et al., 1993; Mulpeter &
Rosenfield, 1993; Stanners, et al., 1993; Kidd, et al., 1993; DePippo, et al., 1994; Hardy, 1995; Davies, et al., 1995; Dworkin & Culatta, 1996; Aviv et al., 1997; Avery-Smith, et al., 1997; Daniels, et al., 1997; Smithard et al., 1998; Daniels, et al., 1998; Addington, et al., 1999; Bastian & Riggs, 1999; Tanner & Culbertson, 1999; Teramoto & Fukuchi, 2000; Smith, et al., 2000; Louis & Ruscello, 2000; McCullough, et al., 2001; Mann, 2002; Ross-Swain, et al., 2003) also revealed that it included all domains necessary to adequately describe the swallowing abilities/disabilities of an individual with dysphagia. Validity of the developed protocol was assessed and confirmed by three experienced speech language pathologist. This tool involved an administration time of 15-20 mins for the experienced clinicians. The tasks included sensory assessment, motor assessment and assessment of phases of swallowing.

Oral sensation involves the integration of touch, taste, temperature, olfaction and somato sensation by the orbito frontal cortex. The swallow reflex is initiated by the sensory input from the peripheral oropharyngeal cavity as well as from the higher order nervous system. Though, the neural correlates of sensation during swallowing are not entirely known, it is known that the placement of food/liquid into the sensory field of oropharyngeal cavity and hypopharynx initiates the swallow response. Food boluses placed in the oropharyngeal region does stimulate multiple fibers in the trigeminal nerve. Tactile sensations such as particle size and texture stimulates the mechanoreceptors, whereas the temperature sensation stimulates thermoreceptors. Taste is stimulated by the receptors in the taste buds of tongue, soft palate, pharynx, larynx and epiglottis (Duffy, 2007). It has also been reported that assessment of sensory skills are foremost important in the management of swallowing disorders.
In the present study, touch/tactile and proprioceptive sensation was primarily addressed, as it involves the ability to locate and move the bolus in oral cavity. Tactile sensation was assessed through light touch and deep pressure on structures such as cheeks, lips, tongue, palate, teeth and gums. Information on other sensations like taste and temperature were gathered during the case history. The information thus arrived, can be used for indicating the severity of sensory problems associated with swallowing in various regions of oral cavity. Moreover, the procedural aspect of closing eyes during the assessment helped in the elimination of bias. The responses were scored as either normal or deviant on a two point rating scale, with scoring of 0 for normal functional limits and 1 for impaired function. Impaired sensory skills indicate either hypersensitivity/hyposensitivity in the target articulator.

The results of sensory assessment scores in adults and geriatrics revealed that there was a significant main effect between the means of groups at p<0.05. Results of post hoc analysis failed to reveal any significant difference between groups I and II. This indicates that sensory skills assessed were within acceptable limits in young and middle aged adults i.e., groups I and II. However, there was a significant difference observed between groups I & III, groups I & IV, groups II & III, and groups II & IV. This suggests that sensory skills are affected in geriatric groups. It was also observed that mean scores increased from group III to group IV suggesting that with the advancing age, impairment of sensory skills increases. This is in consonance with earlier findings demonstrating diminished sensory discrimination in the elderly
individuals (Aviv et al., 1994; Aviv et al., 1998). Impairment on sensory skills were observed only in some of the individuals across all the groups, more so in group IV. These impairments were observed only for the parameter targeting the posterior one third of the tongue (gag reflex) (Davies, Kidd, Stone, & MacMohan, 1995) and it was observed in both the genders with no significant difference between males and females, suggesting that functioning of the touch sensation was not affected by gender.

Oromotor skills are essential for chewing and swallowing. It involves the use and functioning of various articulators such as the lips, tongue, jaw, teeth, hard palate and soft palate during swallowing. These articulators modulate the range of motion, speed of motion and strength of the articulators and also the inter-articulatory coordination. Such a movement and coordination among these structures are crucial for safe swallowing and speech production. Any problems encountered in the oromotor skills affects the precision of movements resulting in swallowing difficulties. These difficulties would lead to unsafe swallow which may sometimes cause aspiration pneumonia. Hence, the assessment of motor skills are of foremost importance in the management of swallowing disorders (Stanners, et al., 1993; Mann, 2002; Ross-Swain, et al., 2003).

In the motor assessment of swallowing, lips, tongue, cheeks, jaw, soft palate, pharynx, and larynx were assessed for the structural and functional intactness. The aspects of articulatory structures were not scored, but were documented. The assessment of function of the articulators was scored on a three point rating scale, i.e., 0-within functional limits, 1- mild to moderate impairment, 2-severe impairment). This three
point rating scale was followed to minimize the variability among the professionals in administration and scoring of the developed protocol.

The results of oral motor function assessment revealed that there was a significant main effect between the means of groups in the motor assessment of swallowing at p<0.05. Results of post hoc analysis revealed that there was no significant difference between groups I & II, and group I & III. This indicates that motor skills tested are intact in young and middle aged adults i.e., groups I and II. However, there was a significant difference observed between groups I & IV, groups II & IV, and groups III & IV. This suggests that motor skills related to swallowing are affected in geriatrics group over 60 years. It was observed that mean scores increases from group III to group IV suggesting that with the advancing age, impairment on motor skills increases. Number of individuals affected on motor assessment of swallowing increased from group III to group IV. This is in consonance with previous observation, demonstrating diminished motor skills related to swallowing in the elderly individuals (Baum & Bodner, 1983; Jahnke, 1991; Robbins, Levine, Wood, Roecker, & Luschei, 1995; Dejaeger, Pelemans, Ponette, & Joosten, 1997; Schindler & Kelly, 2002). This data suggests that the neuromuscular reservoir is affected in geriatric groups in comparison to adult groups. This was observed in both the genders with significant difference between males and females suggesting that motor skills related to swallowing were affected more in females in comparison to males. Need to mention about aging

Importance of trial swallows for the assessment and management of swallowing disorders has been stressed in the literature (Logemann, 1983, 1998; Hinds & Wiles,
From our clinical experience, it is understood that people with poor oral control, reduced laryngeal closure and delayed pharyngeal swallow are comfortable with thickened liquid first and people with reduced tongue base or pharyngeal wall contraction are better with thin liquids. Hence the trial feeds should typically involve dry swallow, thick liquid swallow, thin liquid swallow and solids for understanding the swallow behavior. Swallowing assessment protocol that was developed involved trial feeds, which began with a dry swallow followed by thick liquids, thin liquids and solids. The trial feed consistency adopted for this protocol was adhered to during the assessment. Rice flakes were chosen for the assessment of trail feeds as these are commercially available and inexpensive. The uniformity in the bolus consistency is thus achieved by following the formula suggested in this protocol. The risk for aspiration was also taken care by contraindicating trial feeds in individuals with recent and continuous aspiration, impairment of mental status, lack of laryngeal elevation during dry swallow and weak cough.

In the present study, trial feeds were employed only if the individual was alert, sitting in an upright position with the well aligned body, and preferably hungry. Testing began with a dry swallow. Only after the observation of laryngeal elevation on dry swallow, the testing proceeded with the trial feeds. Otherwise, testing was discontinued. The protocol developed for trial swallows was adopted for further assessment of trail feeds, with 5 ml thick liquid, 10 ml thick liquid, 5 ml thin liquid, 10 ml thin liquid, 90 ml thin liquids and solids. The swallowing parameters were observed and scored for each trial feeds. All the responses were scored on a 3 point rating scale (0-Within functional limits, 1-Mild to moderate impairment, 2-Severe
impairment). This protocol was recommended for individuals with neurogenic dysphagia as they have more problems with thin liquids. But, individuals with mechanical dysphagia have more problems in bolus preparation and hence the testing begun with dry swallow, thin liquids and then proceeded towards thick liquids and solids.

Results of phases of swallowing for trial feeds revealed a significant main effect between the means of groups in the assessment of phases of swallowing at p<0.05. Results of post hoc analysis revealed that there was no significant difference between groups I & II, and group I & III. This indicates that swallowing measures are intact groups I, II and III. However, there was a significant difference observed between groups I & IV, groups II & IV, and groups III & IV. This suggests that the phases of swallowing are affected in geriatric groups. It was observed that mean scores increased from group III to group IV suggesting that with increasing age, impairment on swallowing increases. This was observed in both the genders with no significant difference between males and females suggesting that swallowing phases were not affected by gender. These results support the findings demonstrating diminished sensory discrimination and diminished motor skills related to swallowing leading to swallowing difficulties in elderly individuals (Baum & Bodner, 1983; Jahnke, 1991; Aviv et al., 1997, 1998; Dejaeger, et al., 1997; Nicosia et al., 2000; Schindler & Kelly, 2002).

These impairments on various subscales in the swallowing assessment protocol in geriatric population could be attributed to healthy aging itself. This aging process affects not only the head and neck anatomy but also the underlying neural
mechanisms of the swallowing function. These alterations modify the swallowing mechanism and is called as presbyphagia, which is a naturally diminishing functional reservoir. An effect of age on swallowing was described in the oral cavity, pharynx and esophagus, suggesting that the ageing process alters the pharyngeal and esophageal function (Fulp et al., 1990; Logemann, 1990; Ekberg & Feinberg, 1991; Sonies, 1992; Jaradeh, 1994; Dejaeger & Pelemans, 1996; Nilsson, Ekberg, Olsson, & Hindfelt, 1996; Robbins, 1996; Fucile et al., 1998; Plant, 1998; Ribeiro, Klingler, Hinder, & DeVault, 1998; Wilkinson & de Picciotto, 1999; Nagaya & Sumi, 2002; Schindler & Kelly, 2002; Shaker et al., 2003; Martin-Harris et al., 2005). Other possible explanations could be differences in the respiratory swallow coordination and differences in sensory and motor processes in the swallowing physiology (Chee, Arshad, Singh, Mistry, Hamdy, 2005). Also, the disease prevalence increases with age, and dysphagia is an associated condition in many age-related diseases (Bushmann, Dobmeyer, Leeker, & Perlmutter, 1989; Ekberg & Feinberg, 1991; Daggett, Logemann, Rademaker, & Pauloski, 2006).

The sensitivity of the protocol was tested by administering the protocol on twenty five individuals, 12 with mechanical dysphagia and other 13 with neurogenic dysphagia. The results revealed that the protocol was able to identify dysphagia in various sections of the protocol depending on the impairment. The sensitivity of the test in the detection of aspiration was compared with the Videofluoroscopy results to ascertain whether the protocol accurately identifies the presence of aspiration. This kind of comparison provides a measure of concurrent and criterion validity. The results revealed the following, sensitivity: 77%; Specificity: 67%; Positive predictive value: 71%; Negative predictive value: 73 %; and Efficiency: 72%. This indicates that the
protocol is sensitive in the identification of aspiration in individuals with dysphagia. Longitudinal follow up of these patients during their therapy visits also revealed that the developed protocol was also able to predict changes during the course of therapy and hence this protocol would be of significance in identifying individuals with dysphagia and monitoring the progress during the intervention process.

In a nutshell, swallowing assessment protocol enables the clinicians to identify the presence of dysphagia, to establish possible etiology for dysphagia in relation to swallowing physiology, to assess the ability to identify aspiration, to determine the possibility for oral feeding and to make recommendations regarding the alternative feeding methods and to determine the need for further instrumental evaluation. This protocol provides the qualitative evaluation of elements of dysphagia which can be quantified. It was designed to be administered to all the types of individuals with dysphagia above 18 years of age. The normative data has been established across four different age groups and gender. The same was also administered on a range of pathological conditions (Mechanical dysphagia caused by glossectomy, mandibulectomy etc; neurogenic dysphagia caused by stroke; lateral medullary syndrome; respiratory disorders and psychogenic dysphagia). It was concluded that administering this protocol to all types of dysphagia is appropriate to determine the level of swallowing ability/disability.

Quantitative Measures

**Surface EMG:** Electromyography of muscles involved in swallowing can provide information on the timing and relative amplitude (peak and mean amplitude) of selected muscle contraction during swallowing (Doty & Bosma, 1956; Palmer, 1988;
Palmer, et al., 1989; Perlman, et al., 1989; Perlman, 1993). Ertekin et al. (2001) have commented that the submental muscles play an important role during swallowing. In line with their observation, the submental muscles were targeted in this study to measure the amplitude and temporal components of EMG. The results revealed that the submental muscle functions varies with age, gender, bolus consistency and volume in the normal controls as discussed below.

**Amplitude measures:** It is a well established fact that the muscles always have some electric activity, even during relaxation. After establishing the resting muscle activity for a specific location, muscle activity can be defined as the amount of electrical activity above the baseline. It can also be visualized as an amplitude by time waveform. This amplitude information is proportional to the force underlying the muscle. Peak amplitude of submental muscles in the group I was 65 micro volts, group II was 65 microvolts, group III was 55 microvolts, and group IV was 54 microvolts. Thus, it is revealed that there was a significant main effect of the age group for the peak and mean submental EMG amplitude indicating that the normal aging does influence the submental muscle activity during swallowing. Results of post hoc analysis showed that there was no significant difference between groups I and II. However, changes in the muscle activity was observed from group III onwards i.e., there was a significant difference observed between groups I & III, groups I & IV, groups II & III, groups II & IV. This suggests that the effect of aging on the submental muscle amplitude was evident from 60 years onwards. An effect of age on swallowing was described in the oral cavity, pharynx and esophagus, suggesting that the ageing process does alter the pharyngeal and esophageal function which might have further altered the submental muscle activity during swallowing in the elderly
individuals. Other possible explanations might be the differences in the respiratory swallow coordination and differences in sensory and motor process underlying the swallowing which can have differential effects on swallowing physiology (Chee, et al., 2005). However, Vaiman, et al. (2004) findings reported no significant differences across the age groups. This could probably be due to the smaller sample size they studied in each age group.

Amplitude of submental muscle during swallowing did not vary with gender. This was observed with respect to mean and peak amplitude. This observation is in disagreement with the previous study by, Guttedar, Vivarthini, Balaurbamanium, and Bhat (2009), probably due to smaller sample size in that study.

Bolus consistency was reported to be influencing the amplitude measures of swallowing. The present study also revealed main effect of the consistency on the peak and mean submental EMG amplitude. Results of post hoc analysis revealed that there was a significant difference between the means of dry swallow, thick and thin liquid swallows i.e., as the thickness of the bolus reduces, submental EMG amplitude also reduced by 5 micro volts. So the thick liquid bolus was presented with higher amplitude than the thin liquids. This suggests that the control of thick liquids require more muscle activity at the submental level than the thin liquids, which could be attributed to the role of gravity that is minimized in thick liquids. This is consistent with the previous studies on surface EMG which have reported presence of a significant difference in the mean power values of surface EMG during dry and wet swallowing (Gupta, et al., 1996; Guttedar, et al., 2009).
It is observed that the changes in the bolus volume does affect orophayngeal swallow. The results of this investigation indicated that there were significant differences between the amplitude for the 5ml and 10 ml swallow, with amplitude of the sub-mental musculature increasing from 5 ml to 10 ml swallow by 3 microvolts. This is consistent with the previous studies that mean power values of surface EMG differs between 5 ml and 10 ml swallowing (Gupta, et al., 1996; Guttedar, et al., 2009). This could be due the fact that the demand placed on the submental muscles are more when the volume of the bolus to be swallowed is more and hence the results of the present study.

Temporal measures: Temporal measures in the biomechanics of swallowing do change as a result of ageing. Results of the present study revealed that there was a main effect of the age for the temporal measures i.e., as the age increased, time duration for which the submental muscle activity was present also increased. Results of post hoc analysis revealed that there was a significant difference between the means of all the groups. Younger adults had shorter duration and the older individuals with longer duration i.e., time duration of 1.23 secs, 1.33 secs, 1.38 secs and 1.56 secs for groups I, II, III, and IV respectively. This was attributed to the compensation strategies adopted by the aged individuals for the age related changes in the swallowing musculature (Shaw et al., 1995). The changes in the time duration of submental muscle activity with ageing was observed from 41 year onwards. Hence, it can be assumed that the temporal measures are more sensitive for the identification of swallow deviations compared to amplitude measures. Vaiman (2007) and Aydogdu et al., (2007) has also reported prolonged EMG duration in the elderly individuals than that of adults. In line with this, Shaw et al., (1995) also reported significant increases
in oral transit duration for elderly individuals for all volumes of liquid barium when compared to the younger group. In contrast, Robbins et al., (1992) reported significantly longer durations for pharyngeal transit in the elderly individuals but failed to find an age effect for oral transit duration. These differences are likely due to differences in study protocol of Robbins et al and Shaw et al. where the former administered both liquid and semi-solids as compared to adoption of only liquids by the latter.

Temporal measures of submental muscle activity during swallowing does not vary with gender. This observation is in disagreement with the previous study done on small number of individuals by Guttedar, et al. (2009).

It was evident from the present study that the bolus consistency does influence the temporal measures of swallowing. Results of the present study revealed that as the thickness of the bolus consistency decreased, time duration for the submental muscle activity increased by 0.09 secs i.e., thick liquid swallow was conducted with shorter time when compared to the thin liquid swallow. This could be owing to the fact that the thinner liquids require more pharyngeal and the laryngeal control as they have more chances for entering into the airway, and hence there is a need to prolong the submental muscle contraction in comparison to thick liquid swallows and dry swallows (Logemann, 1998). However, the duration of dry swallow was shorter compared to that of thick and thin liquids. These findings are in agreement with the previous studies (Ertekin et al., 1997; Guttedar, et al., 2009).
Bolus volume does influence the temporal measures of swallowing as evidenced in the present study. Results of the present study revealed that as the volume increased, the time duration decreased by 0.07 secs. These findings are in disagreement with the previous report (Ertekin et al., 1997). Ertekins study could not be relied upon due to the smaller sample size (n=8) considered in their study. The results of the present study could be attributed to the range of pharyngeal and laryngeal control mechanism required for large volume bolus than the small volume bolus (Logemann, 1998; Guttedar, et al., 2009). Though the demand on the pharyngeal and laryngeal control mechanism is more during large volume bolus, it is reflected only in terms of increased muscle amplitude (Logemann, 1998). The time duration did not increase indicating a trade-off relationship between the amplitude and the temporal measures in the submental EMG amplitude. This amplitude time trade off relationship can be observed across all the independent variables considered for the study.

Amplitudes, which correspond directly to the force underlying muscle are the most informative features. Indeed, some investigators believe that amplitude is the only component that has a direct relationship to clinical symptom such as muscle weakness in individuals with neurogenic dysphagia (Wilbourn, 2002). However, in the present study, the temporal measures have been identified to be more sensitive than the amplitude components in the detection of swallowing deviations. The current findings further deepen our understanding about the influence of age, gender, bolus consistency and volume on the amplitude and the time duration of the submental muscle activity during swallowing. The normative data established from the current study can be used to identify swallowing abnormalities and the treatment efficacy. Further investigations are required to correlate the findings on submental EMG
assessment with that of flexible endoscopic evaluation of swallowing (FEES) and/or videofluoroscopy to determine how these EMG values alone predict the abnormalities in the swallowing process.

**Nasal airflow monitoring:** Respiration and swallowing coordinate with each other and ensures proper gas exchange during breathing and prevents aspiration during swallowing (Martin, et al., 1994; Martin-Harris, et al., 2003). Alterations in respiratory (Sekizawa, Ujiie, Itabashi, Sasaki, & Takishima, 1990) and the swallowing mechanism (Tracy, et al., 1989; Robbins, Levine, Wood, Roecker, & Luschei, 1995; Shaw et al., 1995; Nicosia et al., 2000) occurs in healthy aged individuals. Hence, there is a need to establish normative data on breathing and swallowing coordination in adults and geriatrics. This information is critical in the understanding of how the airway is protected during swallowing mechanism which will aid in meaningful intervention (Butler, et al., 2007; Gross, et al., 2009). So, swallow apnea duration and the occurrence of swallow apnea during the respiratory phase were targeted in the present investigation. The results of the present investigation revealed that the respiratory swallow coordination varies across age, gender, bolus consistency and volume in the normal controls. These issues are being adressed here.

**Respiratory swallow phase relationships:** The respiratory swallowing coordination is defined as an occurrence of swallowing apnea in one of the following stages of respiratory phase i.e., during expiration, during inspiration, at the transition between inspiration and expiration or between expiration and inspiration (Bamford, et al., 1992). Literature on these aspects points to the fact that swallowing always
interrupts the exhalation phase of respiration in infants and adults (Wilson, et al., 1981; Weber, et al., 1986; Martin et al., 1994 & Martin et al., 2003). However, this information is reported from the studies where they have used only smaller samples. In the present study, the expiration interrupting the swallowing was the predominant pattern observed in all the groups. This finding is in agreement with the previous research (Nishino, et al., 1985; Selley, et al., 1989; Preiksaitis, et al., 1992; Martin et al., 1994; McFarLand & Lund, 1995; Preiksaitis & Mills, 1996; Hiss, et al., 2001; Hirst, et al., 2002; Martin-Harris, et al., 2003; Hiss, et al., 2004) that exhalation is the preferred phase for the safe swallow to occur. In general, this expiratory phase of breathing is linked to the paramedian position of the vocal fold during the pharyngeal swallow (Schmidt, Holas, Halvorson, & Reding, 1994) but it was not assessed in the present study due to the unavailability of instrumentation at the time of testing. Studies have supported that the paramedian position of the true vocal folds may assist in the airway closure during the pharyngeal swallowing. The paramedian posturing of the true vocal folds appears to protect the airway during swallowing in comparison to the abducted vocal fold position (Schmidt, et al., 1994).

Earlier research has confirmed that transient exhalation often occurs during the descent of the hyolaryngeal complex and then the airway opens (Martin-Harris, et al., 2005). This expiratory airflow helps to drive out the misdirected liquid or food during swallowing (Nishino, et al., 1985; Martin, et al., 1994; Martin-Harris, Brodsky, et al., 2003). Disruption in this aspect often leads to aspiration during the videofluoroscopic examination (Dodds, et al., 1990; Logemann, 1998). Hence the respiratory phase relationship during the swallowing activity is a critical component and should be measured during the swallowing assessment.
In the current investigation, inhalation bracketing the swallow was observed to be high in individuals older than 60 years i.e., in group III and IV. This is in consonance with the previous study by Selly et al. (1989). Inhalation phase of respiration often presents with an abducted vocal fold position which may aid in the entry of food or liquid into the upper airway prior to or during the swallowing. This is of particular concern in individuals with impaired respiratory defense mechanism, such as decreased upper airway sensation and suppressed cough. But these individuals who demonstrated the inspiratory phase pattern did not aspirate during the swallow attempts. This kind of alteration in the respiratory swallow coordination may increase the risk to develop dysphagia and aspiration in individuals with age-related diseases such as stroke or progressive neurologic conditions. Hence, longitudinal investigations are warranted to determine the relationship between respiratory swallowing discoordination, and the occurrence of aspiration in the elderly population and individuals with dysphagia.

**Temporal measures:** The oro-pharyngeal cavity and larynx is a common anatomic area for respiration and swallowing mechanisms. However, both cannot be performed simultaneously i.e., breathing of human beings is arrested for a very short duration during swallowing. This cessation of breathing during swallowing is known as swallow apnea. Little information exists on swallowing apnea duration of healthy adults in the Indian population. Swallow apnea duration, like the phase pattern, changes with age. In the present study, it was observed that group I (young adults) had 1.18 secs, group II (young adults) had 1.42 secs, group III (geriatrics) had 2.28 secs & group IV (geriatrics) had 2.86 secs. The results revealed that there was a significant difference between the means of swallow apnea duration across the age
groups i.e., as the age advanced, swallows apnea duration increased. Results of post hoc analysis revealed that there was a significant difference between the means of all the groups. The prolonged apnea duration was associated with an overall increase in total swallow duration in healthy aging individuals without dysphagia. This is in agreement with the previous studies (Tracy, et al., 1989; Sonies, 1992; Shaker et al., 1992; Robbins, et al., 1992; Shaw et al., 1995; Nicosia et al., 2000) demonstrating the prolonged apnea duration in healthy aged population. Increased apnea duration in the healthy aged population may be a compensatory strategy rather than the result of any impairment in the respiratory swallow mechanism (Shaw et al., 1995). However, this altered age-related pattern may predispose the individual to develop more severe dysphagia and aspiration in age-related diseases such as stroke or progressive neurologic conditions. The results of the present study suggests the use of normative data for the swallow apnea duration when the comparison against disordered swallowing is needed.

There is a significance difference observed across the gender for the swallow apnea duration i.e., females exhibited a longer apnea duration than males. These results support the findings of Hiss, et al. (2001) where significant differences were seen across the gender and contradicts the study by Martin-Haris, et al. (2005).

The results of the present study did reveal significant main effect of the consistency indicating that as the thickness of the bolus increased, swallow apnea duration increased by 0.05 secs. This finding could be attributed to the effect of gravity while swallowing thick and thin liquids. Gravity plays a major role while swallowing thin liquids. As the thin liquids move towards the laryngeal level at the faster pace,
duration of airway protection during the pharyngeal swallow decreases and hence there is a decrease in swallow apnea duration during the thin liquid swallow (Logemann, 1998). However, the role of gravity in thick liquid swallow is lesser than the thin liquids and hence it is expected that the duration of airway protection during the pharyngeal swallow is more during thick liquid.

Significant main effect of volume was observed in the swallow apnea duration indicating that swallow apnea duration increased by 0.07 secs with increase in volume. As the volume increased, more demand is expected at the level of laryngeal valves to protect the airway during the pharyngeal swallow. This demand places the airway in a protective position for more duration while swallowing 10 ml swallow compared to that during the 5 ml swallow (Logemann, 1998). Hence, there was an increase in the swallow apnea duration as the volume increased. This finding is in consonance with the previous findings in the literature (Preiksaitis, et al., 1992; Martin, et al., 1994; Hiss, et al., 2001; Hirst, et al., 2002).

These normatives can be used for detection of deviations in swallowing in the disordered population. Early detection of respiratory swallowing discoordination may help in the identification and prevention of aspiration. However, the evidence for aspiration cannot be ascertained completely from the abnormal respiratory swallow patterns and there is a need for well controlled longitudinal studies to ascertain the relationship between respiration and swallowing discoordination and the incidence of aspiration in clinical populations. The findings of the current study represents an initial step toward this far-reaching objective that has high clinical relevance.
Cervical Auscultation: Cervical auscultation involves the examination of swallowing sounds through the stethoscope microphone placed on the lateral regions of the neck during swallowing (Hamlet, et al, 1990). Some investigators argue that cervical auscultation has tremendous clinical potential in the assessment of dysphagia (Hamlet et al., 1990; Vice, et al., 1990; Nilsson, Ekberg, Olsson, Kjellin, & Hindfelt, 1996; Cichero & Murdoch, 1998) but, it has not been widely used (Logemann, 1998). This lack of clinical application could probably be due to the fact that extensive evidence based research on the appropriate protocol and use of this procedure is not available in the literature (Hamlet et al., 1990; Logemann, 1998; Cichero & Murdoch, 2002). A review of the literature has confirmed that more research is required in the areas of normal swallowing acoustics prior to implementing it in the assessment of dysphagia. More specifically, amplitude and temporal characteristics of the swallowing sounds must be analyzed across multiple food consistencies, for establishing normative ranges and hence these parameters were targeted in the present study. The results of the present investigation revealed that the amplitude and temporal measures of cervical auscultation varies across age, gender, bolus consistency and volume in the normal individuals. The discussion here addresses the temporal and amplitude characteristics of swallow sound.

Amplitude measures: The amplitude of swallow sound was measured in microvolts. The amplitude of the swallow sound indicates the strength of the pharyngeal muscle contraction during the swallowing. In the present study, it was observed that each swallow was accompanied by multiple swallow sounds with the first being the highest in amplitude in comparison to the others. On an average, all the adults in the first two groups were found to exhibit 4-5 swallow sounds and this
number decreased in individuals over 60 years suggesting age related changes in the swallowing action.

In the present study, peak amplitude was 41.32 microvolts, 40.15 microvolts, 30.75 microvolts, and 25.14 microvolts for groups I, II, III, and IV respectively. Results revealed that there was a significant main effect of age group for the peak amplitude. Post hoc analysis of peak amplitude across age failed to show statistical significance between group I and II. However, there was a significant difference between the means of geriatric groups. Similarly, statistically significant differences were observed even for the mean amplitude of swallow sounds. The results of the present study revealed significant main effect of the age i.e., as the age increased, the amplitude of swallow sound decreased. This is in agreement with the previous study by Youmans and Steirwalt (2005) which could be attributed to the age related changes in the swallowing musculature (Fulp & Castell, 1990; Logemann, 1990; Ekberg & Feinberg, 1991; Sonies, 1992; Jaradeh, 1994; Dejaeger & Pelemans, 1996; Nilsson et al., 1996; Robbins, 1996; Fucile et al., 1998; Plant, 1998; Ribeiro et al., 1998; Wilkinson & de Picciotto, 1999; Nagaya & Sumi, 2002; Schindler & Kelly, 2002; Shaker et al., 2003; Martin-Harris et al., 2005). It is also noted that the percentage of individuals who exhibited no swallow sound increased as the age increased. This was more pronounced during the dry swallow in comparison to thick and thin liquid swallow.

Amplitude of swallowing sound does vary with gender with females exhibiting lower values than males. This was observed in both mean and peak amplitude. This is in
agreement with the previous studies by Vivarthini, Guttedar, Balasubramanium, & Bhat, (2009).

The amplitude of swallowing sound varied across the bolus consistency. This was evident in both mean and peak amplitude of swallowing sounds. Results of the present study indicated that as the thickness of the consistency increased, the peak and mean amplitude of swallow sound decreased. This could be because liquids require more pharyngeal and the laryngeal control as they have more chances of entering into the airway. Hence, the muscle contraction required to produce the swallow sound is more for thin liquids in comparison to thick liquid swallows and dry swallows (Logemann, 1998). These findings are in agreement with the previous study by Vivarthini et al. (2009). But intensity of the swallow signal measured by Cichero and Murdoch (2002), was not different across the bolus consistency. These variations in the results could be attributed to the variations in the parameters investigated and the type of microphones used for investigation.

Amplitude of swallow sound also varied with the volume of the bolus swallowed. In the present study, it was observed that as the volume increased, the peak and mean amplitude of swallow sound also increased. This could be attributed to the range of pharyngeal and laryngeal control mechanism required for large volume bolus than for the small volume bolus. As the volume increased, pharyngeal control mechanism increased the demand on the muscular contraction resulting in more muscle contraction leading to increased amplitude of swallow sounds (Logemann, 1998). These findings are in agreement with the previous study by Vivarthini et al. (2009). In the similar line, intensity of the swallow signal was measured across the bolus volume
by Cichero and Murdoch (2002). They did not find a significant difference across the bolus volumes. These variations in the results could be attributed to the variations in the parameters investigated and the type of microphones used for investigation.

Temporal measure: Temporal measures indicate the time duration for which the muscle contraction was observed during the production of swallow sounds. This particular variable has received considerable attention in the cervical auscultation literature. In the present study, the time duration of swallow sound was 0.15 secs, 0.14 secs, 0.11 secs and 0.10 secs for groups I, II, II, and IV respectively. Results revealed that there was a significant main effect of the age with the post hoc analysis revealing significant difference between the means of all the groups except I & II, and III & IV indicating that as the age increased, time duration for the production of swallow sound decreased i.e., younger adults took longer duration and the older individuals with shorter time. This was attributed to the age related changes in the swallowing musculature (Fulp & Castell, 1990; Logemann, 1990; Ekberg & Feinberg, 1991; Sonies, 1992; Jaradeh, 1994; Dejaeger & Pelemans, 1996; Nilsson et al., 1996; Robbins, 1996; Fucile et al., 1998; Plant, 1998; Ribeiro et al., 1998; Wilkinson & de Picciotto, 1999; Nagaya & Sumi, 2002; Schindler & Kelly, 2002; Shaker et al., 2003; Martin-Harris et al., 2005). This finding contradicts with previous work of Youmans and Steirwalt (2005). This is in agreement with the previous studies that acoustic signals related to normal adult swallowing have durations from approximately 0.25 secs to 0.8 secs (Logan et al., 1967; Mackowiak et al., 1967; Hamlet et al., 1992; Takahashi et al., 1994b; Cichero & Murdoch, 2002).
Time duration of swallow sounds did vary with gender and supports the findings by Vivarthini et al. 2009). In contrast, the findings by Youmans and Steirwalt (2005) and Moriniere, Beutter, and Boiron (2006) reported no significant difference between the gender which could be attributed to smaller sample size in their study.

Time duration for the swallow sounds vary across the bolus consistency. In the present study, it was observed that as the thickness of the bolus consistency increased, time duration decreased by approximately 0.05 secs i.e., thick liquid swallow was performed with lesser time duration in comparison to the thin liquid swallow. This could be because thinner liquids require more pharyngeal and laryngeal control as they have more chances for entering into the airway and hence there is a need to prolong the muscle contraction required to produce the swallow sound in comparison to thick liquid swallows and dry swallows (Logemann, 1998). These findings are in agreement with the previous studies (Hamlet, et al., 1990; Vivarthini, et al., 2009) but contradicts the findings by Curren (1992) and Murry & Carrau (2001). It was also observed that dry swallow was presented with lesser time duration when compared to thick and thin liquid swallows.

Time duration for the swallow sounds also vary across the bolus volume considered. In the present study, it was observed that as the volume increased, the time duration of the swallow sound also increased by approximately 0.03 secs. This could be attributed to the range of pharyngeal and laryngeal control mechanism required for large volume bolus than the small volume bolus. As the volume increased, demand on the pharyngeal and laryngeal control mechanism also increased resulting in a prolonged muscle contraction which leads to increased time duration of swallow sounds.
(Logemann, 1998). These findings are in agreement with the previous studies (Boiron, Rouleau, & Metman, 1997; Vivarthini, et al., 2009) and contradicting few others (Cichero & Murdoch, 2002).

These normatives on cervical auscultation across the age, gender, bolus consistency and volume would provide a base for comparison against disordered population. i.e., individuals with pharyngeal wall paresis/paralysis. Further studies are warranted to correlate the findings on cervical auscultation with the occurrence of aspiration in individuals with dysphagia.

In a nutshell, the present study provided the evidence for qualitative and quantitative variation of swallowing behavior across the age, gender, bolus consistency and bolus volume in healthy adults. This information would be of high scientific value for comparison against clinical population.