Advances in Life Science and Technology
ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol 6, 2012
www.iiste.org

Cervical Auscultation: A Systematic Review

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The research is financed by Manipal Foundation, Manipal Uniersity, Manipal, Karnataka, India

Abstract

Cervical auscultation refers to the technique of listening to the sounds of swallowing using a stethoscope or other measurement device such as placing microphone on the surface of the neck. This is based on the assumption that the normal biological sounds will be different from the abnormal biological sounds. The clinical applications of cervical auscultation were reviewed and discussed

Keywords: Cervical auscultation, swallow sounds, swallowing assessment, biological sounds

1. Cervical Auscultation

Cervical auscultation refers to the technique of listening to the sounds of swallowing using a stethoscope or other measurement device such as placing microphone on the surface of the neck (Bosma, 1976). Typically, a stethoscope or a microphone is placed at the lateral aspects above the cricoid cartilage in front of the sternocleidomastoid muscle and the large vessels. This is based on the assumption that the normal biological sounds will be different from the abnormal biological sounds. Stott (1953) and Russell (1956) described the clinical use of cervical auscultation to evaluate pharyngeal swallow and secretion accumulation in bulbar poliomyelitis. In recent years pharyngeal auscultation, usually by stethoscope, has been used by clinicians working with pharyngeally-impaired persons of all ages (Bosma 1976).

In the earlier days, taped cervical sounds have been demonstrated by sonography and described in studies of the infant cry (Truby & Lind 1965; Truby & Lind, 1966a; Truby & Lind, 1966b) and of cry and feeding of infants with cleft palate (Truby & Lind, 1966c). The taped sounds of normal adult pharyngeal swallow have been displayed by sonography and described by Mackowiak *et al.* (1967) and Logan *et al.* (1967). In the recent years, the development of devices such as microphones and accelerometers has enabled digital analysis of swallowing sounds (Mackowiak, Brenman, Friedman, 1967; Logan, Kavanagh, Woniall, 1967; Hamlet, Nelson, Patterson, 1990; Takahashi, Groher & Michi, 1994). This digital analysis techniques has offered the better interpretation of the acoustic swallowing signals, leading to a more accurate examination. They have confirmed that the acoustic analysis of swallow sounds as detected using cervical auscultation can distinguish between dysphagic and non dysphagic individuals (Bosma, 1976 and Mackowiak, Brenman & Friedman, 1967). Zenner, Losinski & Mills (1995) incorporated cervical auscultation with stethoscope into the clinical examination for dysphagia and supported the use of cervical auscultation as a highly sensitive and specific method of dysphagia assessment in long-term care.

Stroud et al. (2002) measured the inter- and intra-rater reliability of five speech and language therapists deciding on aspiration in sixteen swallow sounds. The swallow sounds were recorded simultaneously with VFSS. The authors found a merely fair agreement between the raters. Although the outcome suggests that raters have a high true-positive rate in detecting aspiration, there is a bias for overestimation of aspiration. In the rater-based study by Leslie et al. (2004), intra- and inter-rater reliability of judgments, agreement with the "gold standard" videofluoroscopy, and the association between intra-rater reliability and validity were measured. The individual reliability outcomes varied widely and thus agreement between judgments was poor. The rater's average percentage of sensitivity was 62% and that of specificity was 66%. However, when considering the decision given by the majority of each group, the group consensus values improved to 90% specificity and 80% sensitivity. The authors

therefore conclude that improving the poor raters would improve the overall accuracy of this technique in predicting abnormality in swallowing. Borr, Hielscher-Huckabee, Coombes & Robb (2005) investigated the repeatability of the acoustic swallowing pattern in normal adults and the findings revealed that the acoustic signal is repeatable and suggested the use of it in the clinical practice of dysphagia. Borr, Fastabend & Luking (2007) concluded that the cervical auscultation contains audible cues and acts as an early warning system for identifying patients with a high risk of aspiration/penetration.

1.1 Description of swallow sounds

The acoustic signal generated by the act of swallowing has been described as consisting of two distinct temporal components, sounding like a double click (Lear, Flanagan & Moores, 1965; Logan, Kavanagh & Wonall, 1967; Mackowiak, Brenman & Friedman, 1967). The physiologic correlates of the swallowing sound are assumed to reflect the action of pharyngeal walls. Lear, Flanagan & Moores (1965) suggested that this acoustic event reflects the parting of the mucus membrane surrounding the pharyngeal cavity as the bolus flows through the pharynx in to the pyriform sinuses. Hamlet, Nelson & Patterson (1990) correlated the acoustic swallowing signal with the simultaneously recorded videofluroscopic data. These investigators reported that the signal corresponded to rapid passage of the bolus through the lower pharynx into the oesophagus as well as structural movement associated with the deflection of the epiglottis or hyolaryngeal excursion. Cichero & Murdoch (1998) reported that the vocal tract consists of a variety of valves whose configuration changes during the act of swallowing. These changes reflect the acoustic event of swallowing sound.

Majority of these studies have reported the spectral and temporal aspects of swallowing sound during the swallowing of various boluses and volumes of food material. Some parameters of digital assessment of swallowing sounds in adults have already been identified, such as duration, intensity, and spectral content width and amplitude.

1.1.1 Cervical auscultation in infants and children

Very few studies have attempted to characterize the acoustic properties of swallow sounds in infants and children. Vice, Heinz, Giuriati, Hood & Bosma (1990) was the first one to record the sound signals during suckle feeding of six normal infants within the first two postnatal days. The sounds were recorded onto a cassette tape-recorder from a small microphone attached to the infant's neck, then displayed on an oscilloscope and analysed by digital signal processing techniques. Results indicated the presence of discrete sounds which precede and follow the bolus transit sound. These sounds are consistent during swallows of rhythmic suckle feeding and in the single or few swallows of non-rhythmic feeding. During sequences of rhythmic suckle feeding, the discrete sounds approximate the sounds of the swallow breath; the final discrete sounds (FDS) immediately preceding expiration and the initial discrete sounds (IDS) are in near continuity with inspiration. IDS and FDS are usually brief and are not identical in form. Within a rhythmic feeding sequence, successive IDS and FDS are each similar in form to those respective sounds in succeeding and preceding swallows. IDS may be repeated in a highly similar form. The discrete sounds were limited to a single monophasic or biphasic deflection, with a duration of 10 to 30msec.

Vice, Bamford, Heinz & Bosma (1995) reported that the pharyngeal swallows during infant suckle-feeding are associated with a characteristic sequence of sounds audible by stethoscope or by an accelerometer or microphone held over the larynx. In rhythmically feeding term-born neonates, the delineating acoustic elements are discrete sounds which precede and succeed pharyngeal swallows. Digital signal processing shows similarities in morphological detail between the discrete sounds preceeding swallows and between those succeeding swallows; those succeeding swallows are more variable in temporal relation to swallows, amplitude and morphological detail. Variations in the pattern of interswallow respiration, including apnea, are correlated with variations in the discrete sounds. Specification of physiological correlates of these internal feeding sounds increases the utility of cervical auscultation as a method of investigation and of clinical observation of feeding.

Reynolds, Vice, Bosma & Gewolb (2002) investigated swallow-associated sounds in preterm infants. Twelve recordings of accelerometric and physiological data on bottle-feeding preterm infants between 32 and 39 weeks postmenstrual age (PMA) were analyzed. Cervical auscultation was performed using an accelerometer attached over the larynx. Acoustic data were recorded and graphically displayed using DSP software. Initial discrete sounds (IDSs)

were identified and used to construct an average waveform from which a 'variance index' (VI) was calculated for each infant. The shape of the IDS waveforms became progressively more uniform with advancing PMA, as indicated by a significant inverse correlation between VI and PMA.

Almeida, Ferlin, Parente & Goldani (2008) investigated swallowing sounds by digital cervical auscultation in children of 3-11 years without symptoms of oropharyngeal dysphagia. Digital cervical auscultation was performed in 118 subjects by use of a piezoelectric microphone. The children swallowed 5 ml of liquid and yogurt. The components of perceptual acoustic analysis were discrete initial signal (DIS), main signal of swallowing sound (MS), discrete final signal (DFS), and expiratory return (ER). Duration in seconds was the objective parameter of the swallowing sound signal analyzed. Results indicated a complete DIS-MS-DFS-ER swallowing sequence in 60% of the children. There was no significant difference in swallowing sound duration between both food consistencies or between genders either for liquid or yogurt. There was no correlation between age and duration of the swallowing sound for liquid or yogurt.

1.1.2 Cervical Auscultation in adults

Cervical auscultation in adults have received considerable attention since 1960s. Lear et al. (1965) first examined the dry swallows in young non dysphagic adults and found a spectral peak at 4600 Hz with an average swallowing duration of 500msec. Logan et al. (1967) examined the wet swallow in non dysphagic individuals and reported a spectral range of 0-8000 Hz with the swallowing duration ranging from 250-900 msec. Hamlet, Nelson & Patterson (1990) examined the liquid barium swallows in nondysphagic individuals and reported two distinct spectral peaks at 556 Hz and 1384 Hz, which correspond to the perceived double click as reported by Lear et al (1965). Hamlet, Patterson, Flemming & Jones (1992) compared the spectral and the temporal measures during the wet and paste swallow. They found the wet swallow to have a longer duration (500msec) and lower spectral prominence (1500 Hz) in comparison to duration and spectral prominence of paste swallows (250 msec and 2200 Hz, respectively). Takahashi, Groher & Michi (1994a) examined the wet swallows of non dyshagic adults 22-41 years during successive swallows. Regardless of the number of the swallowing repetitions, two distinct spectral peaks were found to occur at approximately 45Hz and 620 Hz, respectively. The duration of swallows were consistent across the repeated trials, with the mean duration of 529msec. Boiron, Rouleau, & Metman (1997) examined wet and yoghurt swallows in non dysphagic adults aged 18-26 years and reported an increase in the duration of the swallows corresponding to increases in bolus volume. The duration of both wet and yoghurt swallows ranged from approximately 500 to 1000 msec. However, the most comprehensive study on the same aspects was performed by Cichero & Murdoch (2002). They sampled the individuals aged 18-67 years of age during the swallowing of three volumes of thin liquids. Results indicated a tendency for swallowing duration to increase with age, with an overall mean duration of approximately 400 msec. However this pattern was only found for the smallest volume of liquids. Across all the ages, there was a tendency for swallowing duration to decrease with increase in bolus volume.

Youmans & Steirwalt (2005) characterized acoustically normal swallowing in ninety-seven healthy adult participants who consumed teaspoon boluses of various consistencies while the sounds of swallowing were recorded. Descriptive statistics were reported for measures of duration, intensity, and frequency of the acoustic swallowing signal. Correlations between the variables and between bolus consistencies were computed. Significant correlations were found among several of the variables, including an increasing duration of the acoustic swallowing signal with increasing age and decreasing intensity of the signal with increasing age. None of the variables differed significantly as a function of gender. Of potential clinical relevance, significant correlations between bolus consistencies for the duration and intensity variables indicated relative similarities across bolus consistencies. Duration and intensity of the acoustic signal appeared to be the most reliable of the variables measured. These results could serve as a reference point for future studies into normal swallowing across multiple bolus consistencies and volumes and eventually be compared with disordered swallowing.

Moriniere, Beutter & Boiron (2006) used the numeric acoustic recording technique for analyzing swallowing sound signals in healthy subjects while they ingested a defined volume and consistency of a specific substance. Twenty males and ten females were included in the study and given 10 ml of a barium suspension to swallow. A microphone

was placed on the skin overlying the lateral border of the trachea, directly under the inferior border of the cricoid, and connected to a computer. For each sound recording, the total duration of the sound (td), the number (n) of sound components (SC), the duration of each SC (c1, c2, c3,...), and the intervals (i1, i2,...) between the SCs were measured. For all the recordings, the mean durations of acoustic parameters (TDm, C1m, C2m, C3m, I1m, I2m) were calculated and compared by using Student's t test. In the 20 male subjects, the mean acoustic parameters were calculated (MTDm, MC1m, MC2m, MC3m, MI1m, MI2m) and compared with the mean acoustic parameters (FTDm, FC1m, FC2m, FC3m, FI1m, FI2m) in the ten females by using a Wilcoxon nonparametric statistical test. They were able to interpret 80% of the recordings. The TDm was 710 +/- 28 ms. Three main SCs were detected: C1m = 100 +/- 56, C2m = 150 +/- 90, C3m = 80 +/- 54 ms; I1m = 100 +/- 66, I2m = 190 +/- 120 ms. No significant difference in these parameters was observed with respect to gender. Reynolds, Vice & Gewolb (2009) compared the initial discrete sounds (IDS) of adult swallows and compared the stability of IDS signals in infants to that of adults. They performed cervical auscultation with a microphone and accelerometer fixed simultaneously to the neck of 20 healthy adults. Each participant consumed a liquid, puree, and solid. The microphone and accelerometer collected signals of similar duration. The variance index (VI), an assessment of the stability of the IDS, was compared in adults and a group of low-risk preterm infants. The VI of adults swallowing liquid (29.1 [24.1, 36.6] {25%, 75%}) did not differ from that of preterm infants older than 36 weeks PMA (36.3 [33.4, 41.9]), but was lower than the VI of infants younger than 36 weeks PMA (49.0 [46.4, 51.1]; $p < 0.05$). The stability of IDS of low-risk preterm infants approaches that of normal adults as the infant ages.

1.1.3 Cervical Auscultation in dysphagic individuals

A small body of research exists that profiles the acoustic properties of the swallowing produced by dysphagic individuals. Hamlet et al. (1992) examined adults ages from 41-71 years of age who were post laryngectomy. Swallowing signals were obtained for swallows of both wet and paste swallows. The dysphagic individuals demonstrated no significant difference in the duration and spectral prominence of swallows according to wet and paste swallows. Uyama et al (1996) examined the barium swallows of pre and post surgical head and neck cancer patients. The average swallow duration of approximately 1600 msec was reported.

Reynolds, Vice & Gewolb (2003) investigated cervical accelerometry and DSP at a higher sample rate than previously used (22 kHz versus 16 kHz), in conjunction with a DSP software package. The modified Variance index (VI) method was then used to measure developmental differences in the IDS morphology of infants with and without bronchopulmonary dysplasia (BPD). VIs were calculated for 24 feeding studies of infants between 32 and 39 weeks Postmenstrual age (PMA). They included 12 studies on healthy preterm infants (n = 10: three males, seven female; mean gestational age [GA] 28.6 weeks, SD 0.4; mean birthweight [BW] 1080 g, SD 82; PMA mean 35.2 weeks, SD 0.6) and 12 studies on infants with BPD (n = 7: five males, two females; GA 27.1 weeks, SD 0.4; BW 911 g, SD 71; PMA 36.2 weeks, SD 0.6). There was a significant inverse correlation between VI and PMA for the healthy preterm group. There was no significant correlation between VI and PMA for the BPD cohort. The VI of infants with BPD was significantly different from that of infants without BPD ($p < 0.007$, multiple regression analysis, interaction PMA x Group).

Nobrega, Boiron, Henrot & Saliba (2004) assessed the pattern of swallowing between the period of tube-bottle (TBF) and bottle (BF) feeding by means of cervical auscultation in premature infants. Twenty-three premature infants were enrolled (mean gestational age 34.7±1.7 weeks). Audiosignal recordings were made during TBF and BF with a small microphone set in front of the cricoid cartilage. The following parameters were calculated for 2 min and reported at 1 min: the percentage of time involved in swallowing (ST), the numbers of swallows (SN) and swallowing bursts (SB) and swallowing groups (SG). Individual histograms were established to show the individual pattern of swallowing behaviour and the distribution of groups, bursts and swallows over 2 min. Mean (STm), (SNm), (SBm), (SGm) values were calculated (±S.D.). Statistical analysis was used to compare the means and to establish correlations between parameters and curves. STm, SNm and SBm increased significantly during BF compared with TBF for all premature infants and during follow-up. The histograms showed that in BF the groups were high in bursts. These findings and the histograms for each infant allowed the determination of transition to bottle feeding without risk corresponding to the stage of maturation of swallowing function.

Marrara, Duca, Dantas, Voi Trawitzki, de Lima & Pereira (2008) related the data obtained in the clinical and in the videofluoroscopic evaluations of swallowing in children with neurologic disorders. A retrospective analysis of 24 protocols of speech-language evaluation and of medical records of children, of both genders, referred to clinical and videofluoroscopic evaluations of swallowing at the School of Medicine of Ribeirao Preto –University of Sao Paulo, from January 2001 to June 2005 were analysed. The following aspects were analyzed in the clinical evaluation: diet consistency, functional aspects of the swallowing mechanism and results of the cervical auscultation. Videofluoroscopic evaluation was performed to determine the dynamic aspects of the oral and pharyngeal phases. Clinical evaluation of the oral phase, for both liquid and pasty consistencies indicated a greater occurrence of inadequate bolus control. In the pharyngeal phase, also for both consistencies, an adequate cervical auscultate was more frequently observed before swallowing followed by the inadequate cervical auscultation during swallowing. In the videofluoroscopic evaluation, during the oral phase, for both consistencies, the presence of inadequate food propulsion was the most frequent finding and, in the pharyngeal phase, the most frequent finding was the absence of laryngotracheal aspiration. There was a statistically significant correlation between the cervical auscultate and the excursion of the hyoid and the larynx, and between the cervical auscultate and laryngotracheal aspiration of liquid and pasty consistencies. However they concluded that both procedures were important and complementary in the diagnosis of dysphagia.

Santamato et al. (2009) performed acoustic analysis of swallowing sounds, using a microphone and a notebook computer system, in healthy subjects and patients with dysphagia affected by neurological diseases. Data from a previously recorded database of normal swallowing sounds for 60 healthy subjects according to gender, age, and bolus consistency was compared with those of 15 patients with dysphagia from a university hospital referral centre who were affected by various neurological diseases. Mean duration of the swallowing sounds and postswallowing apnoea were recorded. Penetration/aspiration was verified by fibreoptic endoscopy of swallowing in all patients with dysphagia. The mean duration of swallowing sounds for a liquid bolus of 10 ml water was significantly different between patients with dysphagia and healthy patients.

2. **Conclusion**

To conclude, it is clear that there appears to be no consistent pattern available for acoustic event of swallowing in normals due to the variations in the instrumentation used. Apart from the perceived double click pattern in the acoustic signal, temporal and spectral properties of swallowing sounds have revealed varied findings. There are methodological issues related to these aspects which poses a challenge to swallowing assessment in the Indian context.. Some of these issues include chronological age, gender, bolus type and the bolus volume considered in these studies. The majority of the previous researches have not examined the influence of age and gender on the swallowing event. These studies have also varied the type and volume of bolus. In view of the influence of the bolus type, volume, chronological age and gender the swallowing pattern, there is a need for systematically exploring these aspects with the development of normatives. However studies on individuals with dysphagia revealed significant differences between dysphagic and non dysphagic individuals. Hence it can be regarded as a tool for the assessment of dysphagia

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