The Utility of Cervical Auscultation in the Evaluation of Dysphagia

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Introduction

In approximately 6000 B.C., an ancient civilization arose on the plains of Mesopotamia (Piggott, 1961). This civilization, bordered by the Tigris and Euphrates rivers, in the area now comprising portions of Iraq, Iran, and Syria, proved to be surprisingly advanced. By 4000 B.C., several large walled cities marked the area. Though constantly invaded by their poorer neighbors, within these cities architecture, art, written language, mathematics, medicine and science flourished. Archeological investigations have shown that there were individuals identified as "physicians" within the Mesopotamian society. Their understanding of disease and its treatment was an interesting mix of religion, demonology, magic, and herbal treatments. They were severely limited by the absence of medical instrumentation that would allow them to understand the workings of the human organism. Consequently, they functioned with the only information available, the overt symptoms presented by their patients.

Emerging Technology

It is known that during the Mesopotamian era there was widespread exchange of medical information among scholars of the region. Much of the historical information of the time, including that describing medical knowledge from Assyria, Greece, Persia, Egypt, and India found its way as more than half-a-million documents into the Royal Library at Alexandria beginning in 283 B.C. In the greatest loss of accumulated knowledge of humankind, the Royal library burned in 642 AD and its contents were lost (Mellersh, 1994). As a consequence, across the middle ages, Western medicine consisted of increasingly degraded remnants of classical learning from earlier centuries mixed with a healthy dose of folklore and superstition. The understanding of physicians continued to be severely hindered by the lack of instrumentation.

As the curtains of the dark ages parted there was newly inspired interest in science and medicine. The 1600–1800s proved to be a remarkable era of technological development. In a span of only 100 years, the thermometer, microscope, and instrumentation for the measurement of blood pressure and respiration came into being (Trefil, 2001). Equally important was the discovery in 1791 by Austrian physician Leopold Auenbrugger that "percussing" (tapping) on various locations on the chest and abdomen would yield acoustic information that was of diagnostic value (Steudel, 1970). While this was a seminal finding, it remained for French physician Dr. R.T.H. Laennec to develop the necessary instrumentation for widespread use of the technique. It was in 1816 that Laennec first rolled up a tube of paper and held one end to a patient's chest nd the other to his ear (Sakula, 1981). Appreciating the sounds he heard, Laennec then developed a series of devices now known as stethoscopes. The technique Laen-nec developed is "auscultation" and is defined as: "The act of listening for sounds arising within organs (as the lungs or heart) as an aid to diagnosis and treatment, the examination being made either by use of the stethoscope or by direct application of the ear to the body" (Gove, 1981, p. 145). While this classical definition of auscultation has been adequate in the past, it does not reflect the applications made possible by current developments in signal processing technology. Consequently, for the purposes of this article, I will broaden the definition to include the gathering and interpretation of acoustic information that may be made possible, not just through a stethoscope or the naked ear, but also through microphones, accelerometers, and electronic signal processing devices.

Long-Term Care Settings

In the United States, there are over 14,800 free-standing nursing homes (Moody, n.d.). A common characteristic of many of these facilities is a lack of access to common technologies used in the evaluation of dysphagia, especially the videofluoroscopic swallowing study (VFSS). In a study of dysphagia assessment practices in western Washington State, Mathers-Schmidt and Kurlinski (2003) found that 42.2% of their respondents had no access to an instrumental evaluation for those in need of a dysphagia assessment. While the work settings were not identified, it is likely that many are employed in long-term care settings. Clinicians working in these facilities find themselves in a position not unlike that of the Mesopotamian physicians. That is, they are lacking the instrumentation that will allow them to detect covert elements of the condition they study. They are left to rely on the overt symptoms revealed in the clinical swallowing evaluation, an examination that is well recognized to have serious limitations.

While numerous limitations of the clinical examination have been noted (McCullough et al., 2000), the most frequently mentioned is its inability to detect aspiration when it is "silent." Though populations and study methods have varied, it is clear that silent aspiration is a common event. Splaingard, Hutchins, Sulton, and Chaudhuri (1988) found that 42% of their aspirators were of the silent type while Daniels, McAdam, Brailey, and Foundas (1997) and Holas, DePippo, and Reding (1994) found greater percentages, 68% and 72%, respectively. Of great concern is the finding reported by Splaingard and colleagues (1988) that only 30% of profound aspirators (aspirated greater than 10% of bolus) identified on VFSS were also detected by the clinical examination. Finally, Leder and Espinosa (2002) identified still another serious limitation when the clinical examination produced a 70% false positive and 14% false negative rate in identification of aspiration risk. While the false positive errors may result in over referral for instrumental examination, it is this false negative rate that may be of greatest concern because these patients may be judged not to be at risk when they actually are. Any technology that can be applied in the long-term care setting that will improve the identification of true aspirators and true non-aspirators will strengthen the clinical examination.

Forms of Auscultation

To understand auscultation as it might be applied to the swallow, it is important to recognize that it exists in two distinct forms. In the first, the targets of auscultation are the *sounds of the swallow*. Here the investigators capture the acoustic waveform created during the swallow and attempt to tease from it the "acoustic signature" of the swallow. They have then attempted to identify the physiological events that have produced embedded elements of the signature. This form is dependent on signal processing technology. In the second form, the clinician listens primarily to *airway sounds that surround the swallow*. The clinician listens for airway turbulence or a "wet" sound that may be indicative of penetration/aspiration. Only a stethoscope is needed to perform this type of cervical auscultation. Following is a summary of what we know about auscultation according to these two forms.

Swallowing Sounds

Early reports of the evaluation of swallowing sounds began to appear in the mid 1900s (Lear, Flanagan, & Moorress, 1965; Logan, Kavanagh, & Wornall, 1967; Mackowiak, Brenman, & Friedman, 1967). While these authors appreciated the "double click" of the swallow and collected its waveform, they were limited by the technology available at the time. Because the swallow is so fleeting and because there are likely so many acoustic components buried in its acoustic signal, the human ear is not sufficient for processing it in real time. Therefore, this technique requires significant instrumentation, including a device to detect and collect the sound (accelerometer or microphone) and a sound storage/signal processing unit. With this equipment, the investigator can manipulate the signal to focus on individual components embedded in the waveform.

To begin to understand swallowing sounds it has been necessary for investigators to make some important methodological determinations. In two publications (Takahashi, Groher, & Michi, 1994a, b) the authors evaluated the utility of different methods of transducing the sounds of the swallow and concluded that an accelerometer attached to the neck by two-sided paper tape was superior. They reported that the best placement for the transducer was at a midpoint between the center of the cricoid cartilage and the jugular notch where it provided the best signal-to-noise ratio and that placement on either the left or right side produced equivalent results. Cichero and Murdoch (2002), however, are not in agreement, concluding that an electret microphone was superior to other methods in transducing swallowing sounds and that any of four placement sites produced equivalent results.

Investigators have attempted to describe the acoustic characteristics of the "normal" swallow in terms of the shape of the waveform including its duration, peak frequencies, and intensities. Some agreement has been reached regarding the duration of acoustic signature of the liquid swallow. Lear and colleagues (1965); Selley, Ellis, Flack, and Brooks (1990); Takahashi and colleagues (1994b); and Youmans and Stierwalt (2003) all seem to agree that it approximates 500 milliseconds. Such agreement does not exist, however, in regards to the swallow of greater viscosities. While Hamlet, Patterson, Flemming, and Jones (1992) found that a paste swallow was much shorter, approximating 250 milliseconds, Youmans and Stierwalt (2003) found the duration of puree and soft solids are not significantly different from liquids.

When attempting to locate the frequencies of acoustic peaks Mackowiak and colleagues (1967) found an initial 400 Hz "alpha" component followed by a 1,000 Hz "beta" segment. These authors also identified a third sound that was present in wet swallows. Hamlet, Nelson, and Patterson (1990) obtained results that approximated these with an initial peak at 556 Hz and a second peak at 1,384 Hz.

There is also general agreement regarding the amplitude and duration of the first two peaks (Hamlet et al., 1990; Lear et al., 1965; Mackowiak et al., 1967). Generally, the first peak is weak and lasts 30-50 milliseconds. The second lasts from 150-200 milliseconds and is far stronger. If a third peak is seen, it will be weak. While identifying the components of the acoustic signature is important, it only becomes useful when the physiological causes of the events are determined.

Physiological Causes

Cichero and Murdoch (1998) have applied the information they have gleaned to an elegant model they call the "cardiac analogy hypothesis." These authors contend that the swallowing mechanism is, in an acoustic sense, much like the heart for which auscultation has long been relied upon as a diagnostic tool. That is, auscultation of the heart will reveal acoustic events that correspond to:

1. The contraction of muscle (i.e., pumps) with potential for vibration (e.g., ventricular contraction);

2. The movement of valves (e.g., tricuspid valve and mitral valve); and

3. The flowable contents (i.e., blood).

Equivalents exist in the human swallow in the form of muscular contractions (e.g., pharyngeal constrictors, and hyolaryngeal musculature), valves (e.g., the velopharyn-geal closure mechanism and upper esophageal sphincter), and flowable contents (i.e., bolus).

Heinz, Vice, and Bosma (1994) concluded that the acoustic signature of the swallow is composed of components that are tied to specific physiological events. Cichero and Murdoch (1998) have not only hypothesized the sources of these sounds based on their model, but have found support from studies that have used other technologies, namely manometry and VFSS. They conclude that the simultaneous closing of the laryngeal valve and the pressure of the tongue as it makes its first movement against the posterior pharyngeal wall produce the first swallowing sound. As was shown by Takahashi and colleagues (1994a), elevation of the hyolaryngeal mechanism may also contribute to this peak. They believe that the second movement of the tongue against the posterior wall and the pharyngeal clearing wave combine to produce the second peak, one that is stronger and one that lasts longer than the first. Perlman, Ettema, and Barkmeier (2000) found that this second sound does not occur until the bolus was often well into the esophagus and should not be construed as being due to bolus passage through the pharynx. Rather, Hamlet and colleagues. (1990) proposed that this point in the waveform reflects the onset of a pressurized flow of the bolus into the esophagus. Finally, if a third peak is noted, it may be due to an "un-valving" of the system at the conclusion of the swallow.

While these findings tell us something of the form and causes of the acoustic signature of the normal swallow, one test of the technique is in its ability to separate normal from abnormal and/or aspiration events from non-aspiration events. Cichero and Murdoch (1998) discussed the concept of heart murmurs of the stenotic and regurgitive types, suggesting that in a stenotic condition high pressures will be reached as fluid is propelled through a narrow opening. Thus, one might speculate that an achalasia of the UES could produce increased amplitude in the second peak of the waveform. Likewise, a weakness in pharyngeal contractions might reduce the resultant fluid pressure and also affect the second peak, but in an opposite direction.

Uyama and colleagues (1996) analyzed the acoustic swallow signatures of normal and dysphagic swallows. They found significant detectable differences. Swallows without aspiration were shorter than both swallows with aspiration and those with penetration. The maximal amplitude of swallows without aspiration was greater than for swallows with aspiration. Sensitivity (detection of true aspirators) was 87.1% and specificity (detection of true non-aspirators) was 88.9%. Their conclusion was that the acoustic characteristics of the swallow could be used to identify swallows as dysphagic. These same authors (Takahashi et al. 1996) studied a related technique, the use of Soft Expiratory Sounds (SES) that was acoustically analyzed. They found that the technique showed sensitivity of 83.2% and specificity of 82.6%, concluding that it is a viable means of detecting aspiration.

Airway Sounds

The use of auscultation to assess the respiratory system flowed directly from Laennec's original work from which came the technique, the first instruments and the terminology to describe both normal and abnormal breath sounds (Sakula, 1981). For a readable discussion of breath sounds and the techniques of pulmonary auscultation, the reader is referred to Karnath and Boyars (2002).

Auscultation by stethoscope, whether for the purposes of assessing cardiac or respiratory sounds, has not been without problems. It has long been plagued by the inexact nature of the vocabulary used to describe the sounds (e.g., rales, crackles, friction rubs, wheezes, rhonchi, and stridors) and the postulated relationships between the acoustic and physiological events. Patients assume that auscultation is a skill well learned and precisely applied by their physicians. This is challenged by findings of Mangione and Nieman (1999) who, in a study of 627 postgraduate family practice and internal medicine trainees, found *all* of the subjects recognized less than half of all clinically significant respiratory events via pulmonary auscultation. Further, there was little improvement after one year of experience with the technique. This may reflect their additional finding that only 10% of U.S. graduate medical programs offered formal training in pulmonary auscultation. Perhaps it is the subjective nature of the technique that has caused some physicians to no longer rely on it as a diagnostic tool (Gavriely, Nissan, Rubin, & Cugell, 1995). Some speech-language pathologists are leaping into this pot of imprecision as auscultation is proposed as an alternate diagnostic technique for dysphagia. Will we find that auscultation of airway sounds associated with the swallow to be valid and reliable? While experimental data are limited, here is some of what we currently know, but first a brief discussion of the methodology.

Auscultation via Stethoscope

Instrumentation

While auscultation of airway sounds in swallowing can be performed using only a stethoscope, it is important to recognize that not all stethoscopes are created equal. Logan and Kavanagh (1967) reported that energy in the acoustic waveform of the swallow extended to 8,000 Hz, but it seems that most of the critical information (reported earlier in this paper) is located well below 3,000 Hz. It has been concluded that respiratory sounds should typically be assessed using the stethoscope diaphragm, since it responds to higher frequencies. Airway sounds that are associated with aspiration are thought to be low in frequency. It is the bell of the stethoscope that normally responds best to these lower frequencies. Following their assessment of six popular stethoscopes, Hamlet, Penney, and Formolo (1994) identified two that they believe are most appropriate for cervical auscultation of the swallow: the Littmann Cardiology II and the Hewlett-Packard Rappaport-Sprague with medium bell and small diaphragm. Only the Litt-mann Cardiology II met all six established criteria for sound transmission when only the diaphragm was used. This simplifies the selection of the stethoscope and requires that only the diaphragm be used in cervical auscultation. When using a stethoscope with a standard sized diaphragm, the clinician will find a lateral placement will yield improved acoustics. The clinician should experiment with placement and determine which provides the best acoustic results.

Patient Selection

The health status of the patient is an important issue when cervical auscultation of test swallows is considered. If test swallows are to be administered, then the clinician must consider that aspiration is possible. He/she must determine whether the risks associated with potential aspiration are out-weighted by the potential benefits of the information that might be derived from the test. General factors might include patient age, presence of infectious pulmonary disease, coughing with per oral intake, malnutrition, and cognitive impairment. Zachary and Mills (2000) and Mills, Ashford, and Yarber (2004) have determined that there are specific laboratory values that can indicate which patients are, at the time of evaluation, most medically fragile and who may not be able to tolerate the administration of test swallows.

Technique

I use the following procedures when auscultating airway sounds in swallowing. The first step is to select and prepare the test materials that will answer the diagnostic questions posed. In my clinical setting, these most often include ice chips and three liquids. The liquids are keyed to viscosities of regular dietary, nectar-like and honey-like liquids and, perhaps, a thin puree according to recommendations from the National Dysphagia Diet (Clayton, 2002). Though ice chips assume the viscosity of water when melted, they are often presented first due to their less harmful nature if aspirated (Groher, 1984). The clinician should locate him/herself to the front of the patient, such that the diaphragm of the stethoscope can be held with one hand on the skin that overlies the lateral aspect of the thyrocricoid junction. Placement should be sufficiently anterior to minimize interference from the carotid pulse. Tissue coverage of the diaphragm must be complete to allow adequate sound transmission and to eliminate the transmission of airborne sounds.

The clinician should listen across several inspiration/expiration cycles for the presence of turbulence in the airway stream. The normal flow of air should yield a sound that Zenner, Losinski, and Mills (1995) has described as "continuous," "breezy," or "tubular." Turbulent sounds are often discontinuous or interrupted or possess a wet quality. Turbulence present prior to the swallow may indicate the presence of unmanaged oropharyngeal secretions. Once the clinician has determined the nature of the pre-swallow sound, he/she should explain to the patient that the patient will be asked to sip the test material from the cup and should hold it in the mouth until the command to swallow is given. The clinician then hands a cup of the first test material to the patient. It is recommended that the clinician's index finger of the free hand be placed at the midline on the thyroid notch, between the thyroid cartilage and the hyoid bone (Groher, 1984). Finger placement on the structures of swallowing will give the clinician a measure of the promptness of the onset of the swallow and completeness of hyolaryn-geal elevation. The command is then given to swallow. These procedures may need to be modified according to the patient's ability to participate. For example, in some cases it may be necessary to enlist a staff member to administer the test material while the clinician auscultates.

Auscultation of the swallow begins before the swallow occurs, as the clinician listens for premature spillage into the pharynx. As the swallow occurs the clinician should listen for a crisp double-click sound of the swallow, a sound that is reportedly less distinct in the abnormal swallow. Following the swallow, the clinician should again listen through several inspiratory/expiratory cycles for changes in the airway sounds. An increase in airway turbulence may indicate the presence of penetration/aspiration for that bolus.

Because portions of the bolus may be trapped in pharyngeal spaces, Logemann (1998) recommends as part of the standard clinical examination that the patient be asked to phonate "ah," pant for several seconds, and turn his/her head from side to side. These are also appropriate for inclusion when auscultation is added to the clinical swallowing examination. Auscultation following these movements may reveal increased turbulence from dislodged stasis that has now penetrated or been aspirated.

The indicators of penetration/aspiration derived from auscultation may be any of the following:

1. A pattern of normal airway sounds prior to the swallow followed by turbulence following the swallow,
2. Turbulence prior to the swallow that is increased after the swallow, or
3. Turbulence that is first heard or increased following testing of the

movements recommended by Logemann (1998).

Stethoscopic Studies

Zenner and colleagues (1995) evaluated the effects of cervical auscultation to their standard clinical examination of 50 patients in a long-term care setting. They calculated the technique's degree of sensitivity (ability to detect true aspirators) and its specificity (ability to detect non aspirators). Using the Splaingard and colleagues' (1988) data, they calculated that the clinical examination alone had sensitivity of .419. When cervical auscultation was added to the clinical examination Zenner and colleagues (1995) showed a sensitivity for severe aspirators of .842 and a mean specificity value of .710. There were no mild aspirators in the study, so conclusions could not be reached regarding this group. The resultant kappa values were significant at $p < .05$ and below. Thus, these data indicate that the addition of cervical auscultation improved the ability of the clinicians to detect true aspirators. The detection of true non-aspirators was also improved over that expected in the clinical examination.

More recently, Leslie, Drinnan, Finn, Ford, and Wilson (2003) assessed the effect of cervical auscultation of airway sounds by collecting acoustic recordings of 10 normal and 10 penetration/aspiration swallows through a Littmann Cardio III stethoscope during VFSS. These recorded sounds were played for rating and re-rating by 11 speech-language pathologists who were experienced in the use of cervical auscultation. The authors found that 7 of the 11 clinicians were at least "fair" in their judgments. Sensitivity (.620) and specificity (.660) were lower than that found in the study by Zenner and colleagues (1995), but sensitivity was higher than that predicted for the clinical examination alone. Performance across the group varied widely, and, thus, inter-judge agreement was poor. Reliability appeared to be independent of factors that have been assumed to be important such as years of experience, practice pattern, or frequency of use of cervical auscultation. Stroud, Lawrie, and Wiles (2002) found a high degree of agreement when aspirated swallows were rated, but a high level of false-positive errors was found when non-aspirated swallows were presented. The authors question the value of auscultation as a "stand-alone evaluative technique" and suggest that its value may be seen in support of other examination techniques.

Conclusions

At the conclusion of their report on the auscultation of swallowing sounds, Cichero and Murdoch (2002, p. 49) stated "Clinicians should now proceed with the introduction of cervical auscultation into dysphagia clinics." The results from two additional studies reviewed have shown that by this technique it is possible to differentiate between normal and dysphagic swallows and between aspirated and non-aspirated swallows. Further, the studies reviewed in this article show that cervical auscultation of airway sounds add significant information to the clinical examination. The data also show that some individuals are able to reliably detect aspiration in real time via an acoustic signal, but that others cannot. There is a question as to whether these are clinicians who come to the technique possessing a "good ear" and whether that ability can be trained to others who do not seem to have this innate ability.

Given these limitations, should dysphagia clinicians incorporate these technologies into their dysphagia practices? The data suggest that it may well depend upon the skills of the clinician and the purpose for which the technology is used. The results suggest that both techniques can add utility to the clinical examination, but that the limits of the technologies must be appreciated. Detection of abnormality or the presence of aspiration still leaves the clinician with important questions such as, What is the cause of the abnormality? and What is an appropriate management plan? This limitation points specifically to the difference between screening and evaluation tools. The screening tool's function is to detect the presence of a condition and allow triage for further evaluation. The evaluation tool's function is to detect a condition and to describe it sufficiently that its causes are understood and effective treatment planning can take place. It is my opinion, and one that is shared by several other authors (Leder & Espinosa, 2002; Logemann, 1998; Saaski & Leder, 2003; Stroud et al., 2003), that, in their current state of development, both forms of auscultation are best viewed as screening tools. With further development, the procedure may at some point transcend this limitation, but in their current states they have not.

Learning to Ausculate

If a clinician wishes to learn to use auscultation as a screening tool, there are few well-developed options. Karnath and Boyars (2002) have suggested that we take advantage of today's digital technology to create structured training materials designed to teach those who innately do not come to the task with the necessary skills. These courses may be presented on-site or through distance learning. To date, only one such program has been located that has been awarded ASHA CEUs (Logsdon, n.d.). This program presents a discussion of important aspects of auscultation including a review of the respiratory system, presentation of auscultation terminology, and a review of relevant publications. It does not, however, provide experience in judging auscultated sounds of the swallow or of airway sounds surrounding the swallow. Surely, if courses are to be developed to provide skill-based training, then such practice modules will be required.

While formal courses may prove helpful, there is another technique that clinicians with access to VFSS can employ to help train themselves in the auscultation of airway sounds surrounding the swallow. The clinician can connect a contact microphone to throats of patients who are completing the VFSS. The microphone should be connected to an audio input on the VCR, so that the acoustic signal is recorded simultaneously with the video image. Following each swallow of interest, the patient is allowed to inhale and exhale as the transducer collects its information. In this way, on review of the videotape, the clinician's ear can begin to hear what the eye is accustomed to seeing in the fluoroscopy suite when aspiration occurs. While it is true that a microphone is used rather than stethoscope, such practice may still prove beneficial in learning to recognize sounds associated with aspiration versus those where aspiration does not exist. These same videotape recordings could also be provided to clinicians who do not have access to VFSS for use in their own training.

The contributions of auscultation in dysphagia management in the future will be significant. The continued study of the sounds of the swallow will yield a better understanding of the normal and disordered swallow. It is likely that through further study specific physiological swallowing events, both normal and abnormal, will be tied to elements of the waveform. At some point, this form of auscultation may begin to serve us as an evaluation tool that can be applied at the bedside with relatively minimal cost and no radiation exposure to the patient. The cervical auscultation of airway sounds is making a more immediate impact on clinical practice due to the limited equipment that is required, but is likely to remain as a screening tool unless intelligent stethoscopic technology can be brought to bear. With either form, clinicians who undertake their use at the present time must recognize their limitations and understand that they are best used as screening tools.

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Continuing Education Questions

1. Screening tools for dysphagia serve which of the following functions?

a. Detection of a disorder

b. Identification of the underlying cause of the disorder

c. Triage

d. a and c

e. All of the above

2. Which best describes the status of the two forms of auscultation?

a. They are both screening tools.

b. Neither is a screening tool.

c. They are both evaluation tools.

d. None of the above.

3. The Littmann Cardiology II stethoscope was shown to be superior. The author of this article recommends

a. that the diaphragm be used for high frequencies only.

b. that the bell be used for low frequencies only

c. that the bell be used for both high and low frequencies.

d. that the diaphragm be used for both high and low frequencies.

4. Which of the following are true of a test regarding the detection of aspiration?

a. A high specificity value means it is useful in detecting aspirators.

b. A high sensitivity value means it is useful in detecting non-aspirators..

c. A high sensitivity values means it is useful in detecting aspirators.

d. A high specificity value means it is useful in detecting non-aspirators.

e. c and d.

f. a and b.

5. When assessing the sounds of the swallow with signal processing instrumentation a second peak has been identified in the signature of the swallow. It has been postulated that it is caused by

a. movement of the epiglottis and closure of the glottis.

b. the fluid pressure wave as the bolus enters the esophagus.

c. a combination of hyoid elevation and velopharyngeal closure.

d. the flow of the bolus through the pharynx.

e. none of the above.