Material Viscosity Prediction under Normal Swallowing Conditions via High Resolution Cervical Auscultation

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***Abstract*— High resolution cervical auscultations (HRCA), represent a set of promising noninvasive techniques to monitor swallowing activity. In this paper, we investigated the ability to identify the viscosity of swallowed materials from HRCA of healthy subjects. These signals were used to train multiple classifiers and of these classifiers, the Support Vector Machine with the Gaussian Kernel achieved the highest classification accuracy.**

Introduction

Dysphagia is a disorder that is associated with difficulty completing swallows, often resulting in choking, coughing and aspiration into the respiratory system [1,2]. Dysphagia is a fairly prevalent condition, affecting nearly 1 in 25 adults [3].

The current gold standard for dysphagia diagnosis is to conduct a Video Fluoroscopic Swallowing Study (VFSS) in which patients are asked to swallow barium-coated materials of varying viscosities while under X-ray examination [4]. The materials and instruments necessary to complete these studies are expensive, resulting in limited access for smaller clinics. This procedure can also cause discomfort and require patients to be exposed to large amounts of radiation. In the absence of a viable alternative, these sacrifices remain a necessary part of dysphagia diagnosis.

Research has been done to test the validity of Cervical Auscultation (CA) as a possible alternative to VFSS [5]. In CA, swallows are analyzed using devices placed on the exterior of the throat. CA is attractive to smaller clinics for its cost-efficiency as well as its non-invasive nature. However, VFSS still provides a much clearer representation of each swallow [6]. CA also requires a trained professional to perform the procedure. This problem could possibly be eliminated if a computer algorithm were used to analyze the signals instead.

The viscosity of the swallowed material has great effect on the physiological processes of the throat and is heavily considered in the "healthiness" of a given swallow [7]. If a computer algorithm were able to predict the viscosity of materials based on the signals produced during a swallow, it would be a good indication that a computer could make further predictions, such as whether a swallow is healthy or not.

Methodology

The data set consisted of 507 swallows performed by 147 patients and was collected in a previous study. All subjects had no previous history of neurological diseases, swallowing difficulties and/or cancer of the mouth, neck or brain. The patients were asked to swallow thin and thick liquids. During each swallow, acceleration along three axes, and sound produced were recorded. Using the MATLAB statistics and signal processing packages, mean, standard deviation, kurtosis and skewness were measured directly from the signals.

The signals were then processed through a ten-level discrete Meyer Wavelet decomposition. The same statistical features were then calculated from the processed signals in addition to wavelet entropy.

The features deemed important by a random forest importance algorithm were then used to train four different types of machine learning algorithms: logistic regression, linear discriminant analysis, and a support vector machine using a linear kernel and a gaussian kernel. After the algorithms were optimized, one vs. all validation was performed to measure classification accuracy.

Results

It was found that features collected from the acceleration data were most significant in prediction accuracy, which confirms the findings of previous studies. The Support Vector machine with the gaussian kernel vastly outperformed the other three algorithms, achieving 90% accuracy in classification with an AUC of .92. The other three algorithms achieved accuracies of no greater than 60%.

Discussion and Future Directions

The end goal for this research is to develop a classification algorithm that can differentiate between healthy and unhealthy swallows. To achieve this, a much larger dataset of both types of swallows would be necessary. Once an algorithm is trained and optimized, it must be made accessible and easy to use in a clinical setting.

Conclusions

This study showed that it is indeed possible to use signals produced by CA to differentiate between swallowed materials. The results also indicated that the features from swallowing accelerometry are very promising for swallowing analysis and may be useful for dysphagia detection.

References

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