**An Interactive System for Visualizing and Interpreting Propagating Vagal Nerve Activity to Improve the Efficacy of Gastric Electrical Stimulation for Gastroparesis**

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Gastroparesis is a stomach condition that results in abnormal processing of food and delayed gastric emptying without a mechanical obstruction. Nausea and vomiting are the most common symptoms. When pharmaceutical treatments and dietary changes fail to relieve symptoms, a gastric electrical stimulation (GES) device is implanted and used to electrically stimulate the stomach wall. Although the exact mechanism is unknown, there is evidence that GES stimulates the vagus nerve, which is the primary nerve that the stomach uses to communicate sensory information to the brain. We hypothesize that GES relieves nausea and vomiting by stimulating the vagus nerve. Vagal nerve recordings were obtained in human subjects receiving GES for gastroparesis using a novel, noninvasive method, consisting of placing a multi-electrode array (MEA) on the skin surface overlying the left and right cervical vagus nerves. The array allows for visualization of propagating nerve activity that is tied to the electrical stimulus delivered by the GES device. Since nerve signals propagate at specific speeds, the MEA can be used to learn properties of the vagal nerve pathways that transmit information to the brain in response to GES (Fig. 1A). Cervical measurements can also be collected from the subjects to determine optimal placement of the MEA. Due to the complex nature of the data sets collected, it is necessary to simplify the interpretation of the data to ensure that the importance of the signals is understood by a broad audience. A graphical user interface was created as an interactive tool to visualize and interpret vagal nerve activity using the data collected from the MEA. The interface includes a color-coded outline of the cervical measurements obtained on an image of the neck and a description of each measurement in terms of its anatomical position (Fig. 2A). It features an interactive component that allows users to view each measurement individually by selecting the identifying letter representative of each measurement (Fig. 2B). Users can select a subject from a drop-down menu, which results in automatic placement of the MEA on the image using the cervical anatomy measurements specific to that subject. To visualize nerve activity, a colormap is implemented where brighter colors denote activity (Fig. 1B). The data collected and analyzed from the MEA is the 70 millisecond window after each stimulus is applied. To maximize visualization, the rate of the activity is reduced and allows users to control the playback speed of the data using a slider. We are determining the limitations of detecting vagal nerve activity through the skin surface, including body mass index and the parameters of the GES device. Visualizing and analyzing the data traveling across the electrodes may provide insight into the typical anatomical course of the vagus nerve. We aim to use this display of vagal nerve activity to decode and analyze its involvements in GES and the treatment of gastroparesis.

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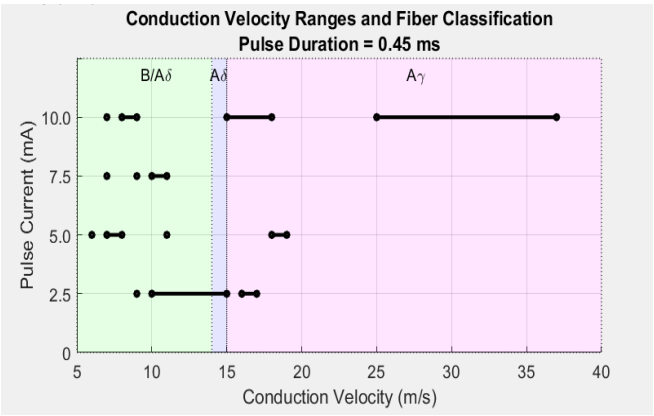
**A. Propagating Features Detected in Response to GES**




**B. Visualization of MEA Placement and Vagal Nerve Activity**

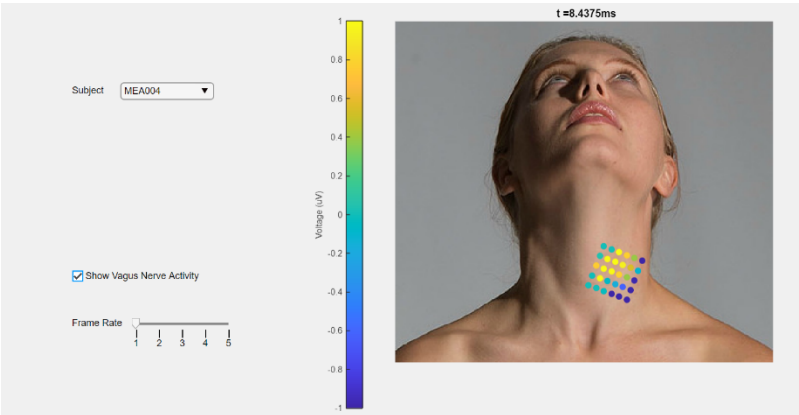
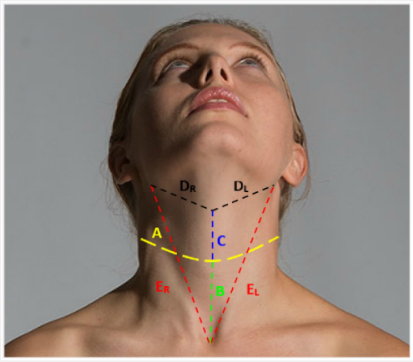



**Figure 1**. (**A**) is a summary of the conduction velocity ranges and nerve fiber classification for propagating activity detected in response to GES with stimulus pulse currents of 2.5, 5.0, 7.5, and 10.0 milliamperes and a pulse duration of 0.45 milliseconds. (**B**) shows MEA placement and visualization of vagal nerve activity. Selection of a subject results in automatic placement of the MEA. The checkbox allows users to view vagal nerve activity, where brighter colors denote propagating activity.

**A. Outline and Descriptions of Cervical Measurements**




| ID | Measurement Description |
|---|---|
| A | Mid-cervical neck circumference at laryngeal prominence |
| B | Suprasternal notch to laryngeal prominence |
| C | Laryngeal prominence to hyoid bone |
| $D_R$ | Hyoid bone to right angle of mandible |
| $D_L$ | Hyoid bone to left angle of mandible |
| $E_R$ | Suprasternal notch to right angle of mandible |
| $E_L$ | Suprasternal notch to left angle of mandible |

**B. Interactive Component to View Measurements**

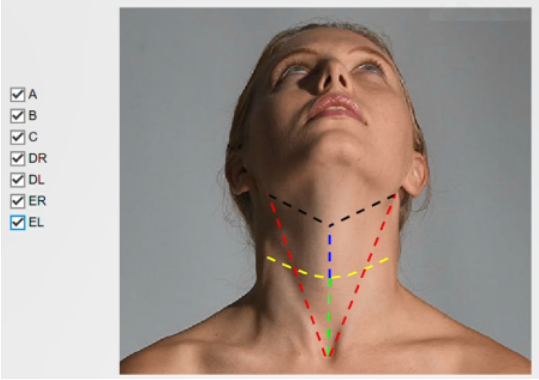



**Figure 2**. (**A**) shows an outline and descriptions of the cervical measurements obtained that were used to determine electrode placement. (**B**) shows an interactive component that allows users to select and view each measurement individually.