RE-EXAMINING THE GEOMETRY OF OPTO-ELECTRONIC PLETHYSMOGRAPHY

JEREMY FAGUE1, DR. DAVID SWINARSKI1, DR. WILLIAM BULMAN2, AND DR. AIMEE LAYTON2

1. Fordham University 2. Columbia University Medical Center

OPTO-ELECTRONIC PLETHYSMOGRAPHY

Opto-Electronic Plethysmography (OEP) is the use of motion capture technology to compute changes in thoracic volume over time in human subjects. Infrared cameras record the positions of 89 markers placed on a subject’s chest, back and stomach. The changes in the volume of the region described by these markers is utilized to analyze the synchrony and mechanics between various areas of the chest wall. Unlike prior forms of ventilatory mechanics measurement, OEP allows for the non-invasive and continuous measurement of chest wall movement at rest and during exercise while demonstrating agreement with prior methods of testing.

MAJOR QUESTIONS

We are investigating whether it is possible to modify the volume-computing algorithms of OEP to extend its usage to a more diverse selection of patients. In particular, we would like to design, develop, and test software to perform two new functions:

1. Approximate the change in lung volume of each lung individually (currently, OEP approximates lung volume changes in aggregate).

2. The current commercial software used for OEP is designed to work for only one configuration of markers corresponding to a subject with normal lung function. We will modify the volume-computing algorithms to allow alternative configurations of markers on the thoraco-abdominal region that will improve the accuracy of OEP in patients with abnormal chest wall configurations, such as post-surgical patients and patients with neuromuscular disease.

MATHEMATICAL FOUNDATIONS

Theorem. Let $T$ be a triangle lying outside a plane $P$, with $T$ and $P$ not necessarily parallel. Then the volume of the region contained between $T$ and $P$ is

$$V = Ah \cos(\theta)$$

where $A$ is the area of $T$, $h$ is the distance from the centroid of $T$ to $P$, and $\theta$ is the angle between $T$ and $P$.

![Theorem Diagram](image)

Cala et al. decompose the thoraco-abdominal region into pieces of this shape. We use this formula to compute the volume of each piece.

REFERENCES


STANDARD VENTILATORY MECHANICS TESTING VS. OEP

The standard measurement of ventilatory mechanics utilizes one of two methods:

1. Esophageal and gastric pressure changes
   - Invasive measurement form that is obtained via a balloon being placed in the esophagus.
   - Difficult to obtain in patients with severe airway disease.
   - Difficult to obtain during exercise.

2. Exercise inspiratory capacity maneuvers
   - Non-invasive measurement of changes in lung volumes that involves performing a breathing maneuver during exercise.
   - Alters natural breathing pattern to obtain data.
   - Does not measure changes in the compartmental mechanics.

In contrast, OEP is

- Non-invasive
- Easy to obtain data during exercise.
- Does not affect the airways or natural breathing pattern.
- Can give information on changes in chest wall mechanics and theoretical changes in utilization of muscle groups during exercise.

THORACO-ABDOMINAL REGION

We are writing computer programs in Visual Basic for Microsoft Excel to compute thoracic volumes. The input to our program is the three-dimensional coordinates of the 89 markers in each frame.

Our first goal is to replicate the results from commercial OEP software to establish the accuracy of our program. We triangulate the surface of the thoraco-abdominal region and choose an arbitrary reference plane. We then use the volume formula shown at left to compute the volume of the region between each surface triangle and the reference plane and its changes through time.

Once we verify that our program is working correctly, we can begin to study the results obtained using different configurations of markers.

PRELIMINARY RESULTS