Bioengineering Day Poster Addendum (ABET Questions)

Group 30: Biomechanical Work Analysis on Patients with Dysphagia Using High-Resolution Manometry and Impedance

1. Desired Needs that led to our final design objectives
    - High-Resolution Impedance Manometry (HRIM) gives raw pressure and impedance signals, but those signals are not always easy for clinicians to directly interpret. We wanted to turn the raw data into more physical and clinically meaningful metrics, such as cross-sectional area (CSA), tension, and mechanical work.
    - We wanted to compare patients before and after treatment in a more quantitative way, so clinicians could better understand whether swallowing function improved after therapy.
    - Another goal was to make the analysis process faster and more automated, so repeated patient datasets could be processed with less manual workload.
    - For the gel portion, we wanted a swallow bolus that was more stable, had a longer shelf life, and still worked consistently with HRIM testing.
2. Major Constraints on our design/project
    - **Safety/Regulatory Affairs**: Since the gel is used in a swallowing study, it must be safe, simple, and compatible with clinical testing. Because the project involved patient clinical data, de-identification, privacy, and responsible data handling were also important.
    - **Risks:** The biggest risks were noisy signals, patient-to-patient variation, incomplete or imperfect data export, and limited sample size. These issues could affect how confidently we interpret the final trends.
    - **Global Impact:** Dysphagia affects many patients and can reduce quality of life. A more quantitative analysis tool could make treatment tracking easier, but it would need to fit into existing clinical workflows to be useful.
    - **Manufacturability:** The gel recipe could not be too complicated. It needed to remain easy to prepare while improving stability, shelf life, viscosity, and conductivity.
    - **Quality Control/Marketability:** For the gel, quality control included checking conductivity, viscosity, visible bacterial growth, and shelf-life stability. For the MATLAB pipeline, quality control included checking channel matching, heatmaps, Upper Esophageal Sphincter (UES) / Lower Esophageal Sphincter (LES) boundaries, and whether the output made physiological sense.
3. Major Engineering Standards relevant to our project
    - Since our project is still a research-stage workflow rather than a finalized clinical device, the most relevant "standards" were consistency standards for clinical protocol, gel property testing, and data processing.
    - The clinical testing protocol had to stay consistent across patients and conditions, including gel vs. solution, 5 cc vs. 10 cc boluses, body position, and pre-/post-treatment comparisons.
    - The gel had target properties such as stable conductivity, appropriate viscosity, longer shelf life, and no visible bacterial growth during storage.

- The MATLAB workflow needed a consistent processing structure: raw HRIM data export, pressure-impedance channel matching, CSA and tension calculation, CSA–tension loop generation, mechanical work calculation, UES/LES segmentation, and regional comparison across the esophagus.
- A future standard from this project could be a clearer workflow for using HRIM and impedance data to report esophageal mechanical work, instead of only relying on standard HRIM plots.

4. Ethical, Environmental, or Societal concerns
    - Because this project used patient clinical data, privacy and responsible data handling were important throughout the project.
    - The results should not be overgeneralized because the patient cohort was still limited, and each patient had different baseline conditions and data quality.
    - This method should be viewed as a supportive analysis tool, not a complete diagnostic replacement for clinicians.
    - Societally, the project could help make swallowing treatment response more understandable for both clinicians and patients by turning complex signals into more tangible metrics.
    - A clearer biomechanical metric may also help patients better understand whether their swallowing function improved after treatment, instead of only relying on abstract signal plots.
5. Active Teamwork and Leadership in our design group
    - Our team divided the work into several parts, including gel reformulation, clinical data export, MATLAB analysis, ultrasound analysis, figure generation, and poster/presentation preparation.
    - We met weekly with our mentor and also held additional group meetings to coordinate progress and combine results from different subprojects.
    - My main contribution was the MATLAB pipeline, including pressure-impedance channel matching, CSA/tension calculation, mechanical work analysis, max pressure-related biomechanical metrics, data export, and figure generation.
    - Teamwork was important because each part affected the next step. For example, if data collection or export had issues, the later MATLAB analysis could show outliers or require manual checking.
    - We also revised our poster based on mentor feedback to make the final story clearer and easier for clinicians and judges to follow.
6. Motivating factors for acquiring new knowledge, being self-initiating, and persisting through challenges
    - This project helped me learn more about dysphagia, Eosinophilic Esophagitis (EoE), HRIM testing, and how swallowing mechanics can be studied using clinical signals.

- Seeing the real HRIM experiment and working with actual clinical data made the project more meaningful, because the data came from real patients rather than a simplified classroom dataset.
- The hardest part was not only coding, but also making sure the results made physiological sense. For example, automatic UES/LES detection still needed to be checked against heatmaps and patient-specific swallow patterns.
- I learned that clinical data analysis requires many layers of validation. A single number or plot is not enough; the result has to be checked against the raw signal, patient condition, and biological interpretation.
- I also learned that in clinical engineering, automation is useful only when it is paired with physiological validation and human review.
- The project showed me how important cross-team communication is in clinical engineering projects, because gel preparation, data collection, export, ultrasound processing, and MATLAB analysis all depend on each other.

7. Most innovative and/or entrepreneurial ideas
   - The most innovative part of our project was converting physiological signals from HRIM into physical biomechanical metrics, especially esophageal mechanical work.
   - This could help clinicians judge treatment response more quantitatively and give patients more tangible feedback about how their swallowing function changed after treatment.
   - The MATLAB pipeline is useful because it can generate multiple outputs from one dataset, including CSA–tension loops, channel-level work, regional work, and pre-/post-treatment comparisons.
   - In the future, the workflow could become more automated, from data import to analysis output, which would reduce manual workload and make the method easier to use in research or clinical settings.
   - Combining HRIM analysis with ultrasound and manual validation also makes the results more reliable than relying on one signal source alone.