Assistive Dysphagia Drinking Straw

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Biomedical Engineering, Biological Sciences, Chemical Engineering, Materials Science and Engineering, Mechanical Engineering

Introduction

- Progressive supranuclear palsy (PSP) affects >20,000 individuals in the US
  - Neurodegenerative disease occasionally leading to frontotemporal dementia
- 80% of PSP patients suffer from dysphagia - difficulty or discomfort swallowing foods and liquids - during their disease progression

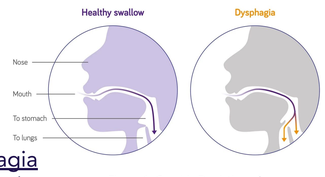


Figure 1: Graphic Depiction of Dysphagia

- Aspiration - food or fluid entering the lungs - often causing choking
- Current dysphagia-targeted solutions do not effectively accommodate the physical and cognitive needs of PSP patients

Needs Statement

A device that addresses dysphagia and frontotemporal dementia in PSP patients, enabling the safe and independent consumption of fluids, effectively reducing the patient's risk of aspiration.

Proposed Solution

Automated Fluted Straw

Our design features an automated fluted straw that regulates both the volume and frequency of fluid consumption for PSP patients.

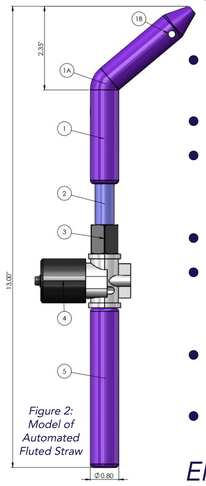


Figure 2: Model of Automated Fluted Straw

Silicone Material

- Flexible yet durable - accommodates user's drinking preferences and physical limitations
- Heat-safe - allows for wide temperature range
- Dishwasher-safe - ensure effective sanitation

1A. Angular Bend

- Enables comfortable drinking at various angles
- Accommodates range of motor skills

1B. Fluted Openings

- Directs fluid toward the sides of the user's mouth, reducing risk of aspiration
- Facilitates drinking fluids of varying viscosities

Electromechanical Fluid Regulation Method

Fluid flow is detected by an ultrasonic sensor and subsequently regulated by a solenoid valve, both of which are controlled via Arduino. The electrical components are directly integrated into the straw tip (Pt.1) and straw base (Pt. 5), via a threaded adapter (Pt. 3). The frequency and volume of fluid dispensation is determined by the selected drinking cycles from the smartphone app (Fig. 5, 6).

2. Ultrasonic Sensor

Measures flow rate of fluid by transmitting ultrasonic waves across the straw, determining suction rate

4. Solenoid Valve

Electromagnet that converts electrical energy to mechanical energy to remotely control the flow of fluid

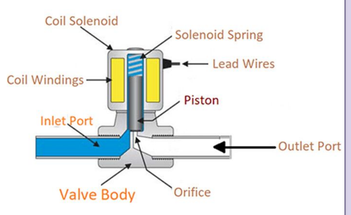


Figure 3: Diagram of Solenoid Valve Components

Testing

Bolus Testing Methods

- Verified ultrasonic sensor flow volume readings
- Set bolus size at 5 mL and poured water through until the solenoid valve closed

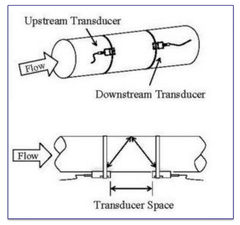


Figure 4: Ultrasonic Flow Sensor Technology

Results

- Percent error could be caused by leakages
- Typical bolus size is 5 - 20 mL, 20% error falls within acceptable tolerances

	Test 1	Test 2	Test 3	Test 4
Actual Volume Poured (mL)	4.0	5.0	5.2	4.4
Percent Error	20%	0%	4%	12%

Durability Testing - Proposed Methods

- Place device in a bag, simulating carrying conditions
- Test with fluids at temperatures from 40-250°F, note any deformation
- Subject silicone portion to bending, testing for inelastic deformation
- Small-scale prototype manufacturing not conducive to conducting accurate durability testing

Manufacturing Methods, Market Analysis, Patent Search, and Reimbursement

Manufacturing Methods

It is anticipated that the straw base and tip will be produced via outsourcing injection molding with Versaflex™ OM 1040X-1 (food-grade silicone) with a press fit threading made of HDPE (food safe plastic).

Estimated Manufacturing Costs

An estimate for the injection molding is not available, however, the price for mass manufacturing will be more cost effective, as a permanent mold will be created. The current utilized a solenoid valve and ultrasonic sensor which cost $17 and $173, respectively. Future prototypes will use higher quality components, whose costs vary.

Market Analysis

As the primary target consumer is individuals with PSP who experience dysphagia but are still able to drink fluids via their mouth, the potential serviceable market is represented by at least 16,000 individuals in the US.

Reimbursement

The device is not likely to be reimbursable by Medicare or Medicaid, as other assistive drinking devices for dysphagia are currently not covered.

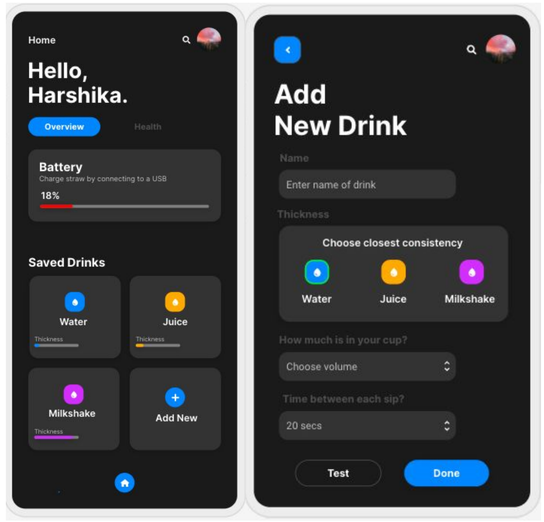
Patentability

- *US20100092309-A1*: patent for straw with a pump apparatus
- Does not mention controlling the amount of liquid dispensed or addressing dysphagia-related aspiration
- Anticipated that the proposed device will be patentable

Conclusions

Design Summary

- PSP patients require a device to mitigate their risk of aspiration
- Developed solution is an electromechanical approach
- Regulates frequency and volume at which fluid is consumed
- Enables safe, independent drinking for range of user preferences



Figures 5 and 6 : Story-Boarded Depiction of Smartphone Application

Future Work

Potential work for the next project iteration includes:

- Injection mold out of silicone
- Develop additional drinking cycles
- Integrate PCB
- Consolidate electronic components
- Build smart-phone app
- Design more straw tips

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References

1) Progressive Supranuclear Palsy. www.hopkinsmedicine.org. https://www.hopkinsmedicine.org/health/conditions-and-diseases/progressive-supranuclear-palsy
2) What are the 4 Stages for PSP? PSP AWARENESS. https://pspawareness.com/blogs/psp-q-a/what-are-the-stages-for-psp-how-many
3) Progressive Supranuclear Palsy (PSP Disease). Cleveland Clinic. https://my.clevelandclinic.org/health/articles/6096-progressive-supranuclear-palsy
4) Progressive Supranuclear Palsy Fact Sheet | National Institute of Neurological Disorders and Stroke. www.ninds.nih.gov. https://www.ninds.nih.gov/progressive-supranuclear-palsy-fact-sheet
5) Progressive Supranuclear Palsy - NORD (National Organization for Rare Disorders). NORD (National Organization for Rare Disorders). Published 2015. https://rarediseases.org/rare-diseases/progressive-supranuclear-palsy/
6) Swallowing Disorders: Tips for Using Food and Beverage Thickeners. www.agingcare.com. https://www.agingcare.com/articles/swallowing-disorders-tips-for-using-food-and-beverage-thickeners-208048.htm
7) Nasogastric feeding tube : MedlinePlus Medical Encyclopedia. medlineplus.gov. https://medlineplus.gov/ency/patientinstructions/000182.htm#:~:text=A%20nasogastric%20tube
8) NHS Choices. Treatment - Dysphagia (swallowing problems). NHS. Published 2020. https://www.nhs.uk/conditions/swallowing-problems-dysphagia/treatment/
9) What is ESP™?. Ampcare ESP. Accessed October 7, 2022. https://swallowtherapy.com/esp/.
10) *Deciphering Dysphagia | National Foundation of Swallowing Disorders.* (n.d.). https://swallowingdisorderfoundation.com/deciphering-dysphagia/
11) *Progressive Supranuclear Palsy.* (n.d.). Ucsfhealth.org. https://www.ucsfhealth.org/conditions/progressive-supranuclear-palsy#:~:text=Progressive%20supranuclear%20palsy%20(PSP)%20is
12) Street, D., Whiteside, D., Rittman, T., & Rowe, J. B. (2022). Prediagnostic Progressive Supranuclear Palsy – Insights from the UK Biobank. *Parkinsonism & Related Disorders, 95*, 59–64. https://doi.org/10.1016/j.parkreldis.2022.01.004
13) Viscidi, E., Litvan, I., Dam, T., Juneja, M., Li, L., Krzywy, H., Eaton, S., Hall, S., Kupferman, J., & Höglinger, G. U. (2021). Clinical Features of Patients With Progressive Supranuclear Palsy in an US Insurance Claims Database. *Frontiers in Neurology, 12*. https://doi.org/10.3389/fneur.2021.571800
14) *Burden among Patients with Progressive Supranuclear Palsy.* (n.d.). MDS Abstracts. https://www.mdsabstracts.org/abstract/burden-among-patients-with-progressive-supranuclear-pals
15) *Progressive supranuclear palsy - Diagnosis.* (2018, August 14). Nhs.uk. https://www.nhs.uk/conditions/progressive-supranuclear-palsy-psp/diagnosis/
16) *TUBE FEEDING Information for people affected by Progressive Supranuclear Palsy (PSP).* (n.d.). Retrieved November 11, 2022, from https://pspassociation.org.uk/wp-content/uploads/2019/05/IS-Tube-Feeding.pdf