Lattice Stent For Improved Fluid Drainage In Post-Surgical Care

Parima Phowarasoontorn, BS[1]; Yongbin Ko, BS[1]; Oraib Al-Ketan, PhD[1]; Juan Barajas Gamboa, MD[2]; Carlos Abril Vega, MD[2]; Juan Pablo Pantoja, MD[2]; Ahmed Alzubaidi, MD[2]; John Rodriguez, MD[3]; Matthew Kroh, MD[3]; Khalil Ramadi, PhD[1,4*]

[1]New York University Abu Dhabi; [2]Cleveland Clinic Abu Dhabi; [3]Cleveland Clinic; [4]New York University

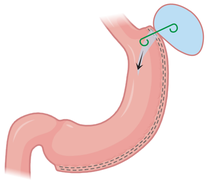
*e-mail: pp2222@nyu.edu, kramadi@nyu.edu

INTRODUCTION

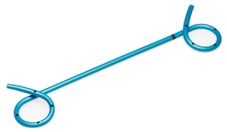
- **Bariatric surgery** aims to treat class III obesity by reducing stomach size to limit calorie intake.
- **Gastric leakage** is a life-threathening complication (1-10% occurrence).
- **Current solution:** Endoscopically insert a double pigtail stent (DPS) to drain the abscess and achieve leak closure.
- **Problem:** Commercially available DPSs are designed for biliary drainage, and the use for gastric leakage treatment is off-label (not optimized for abscess drainage, limited shape and size options).
- **Goal:** Design a stent with enhanced fluid evacuation performance to promote faster recovery



Fluroscopy image of a patient with gastric leakage



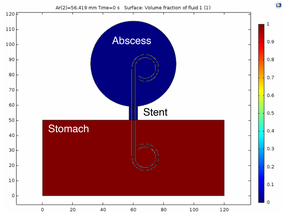
Gastrectomy with leakage and stent inserted



Boston Scientific Advanix™ Biliary stent

METHODS

Computer simulation



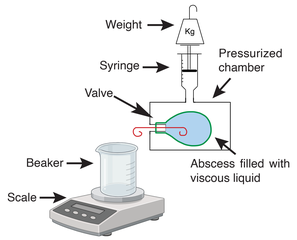
- Analyze how stent and abscess geometry affect fluid flow.
- Software: COMSOL Multiphysics
- Parameters: DPS length, lumen diameter, loop size, fenestration size, tissue clearance, Abscess size and symmetry.

Fabrication



- Find an appropriate 3D printing method and material.
- Printer: Formlab Form 3+
- Material: Flex 80A
- Characterization: Mechanical strength, hydrophilicity, surface morphology, leaching, and bioinertness

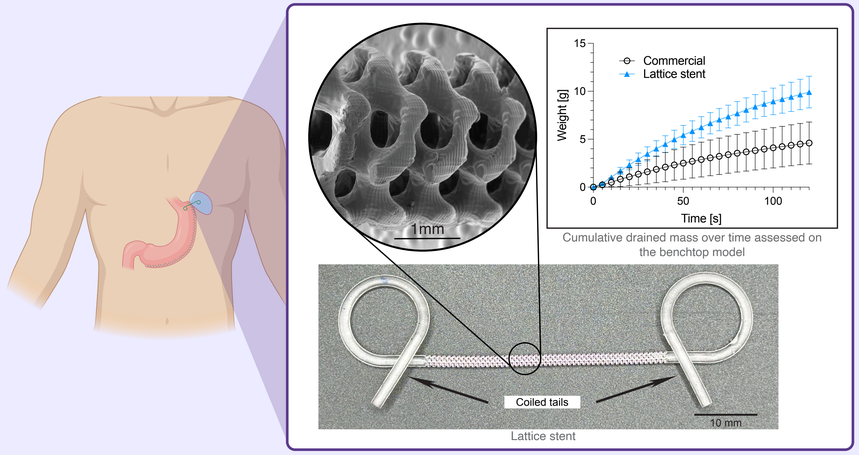
Benchtop testing



- Test the fluid evacuation performance of stent designs.
- The abscess pouch was filled with viscous fluid and subjected to uniform pressure.
- Cumulative mass drained vs. time was recorded.

RESULTS

Our lattice stent (Gyroid UC 1 RD 30) can drain fluid approximately **two times faster** than a commercial double pigtail stent of the same size.



Computer simulation

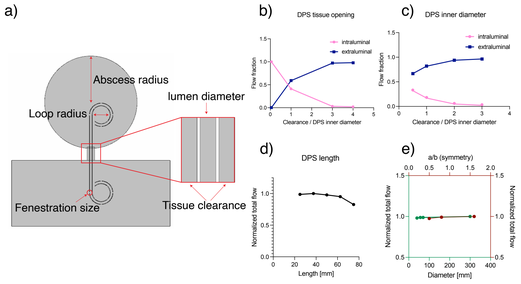


Figure 1. (a) Simulation setup schematic. (b,c) Flow occurs mostly outside the stent as tissue opening size and DPS diameter vary. (d) Shorter stents show 21% higher total flow than longer ones. (e) Abscess size and symmetry do not significantly affect initial flow rate.

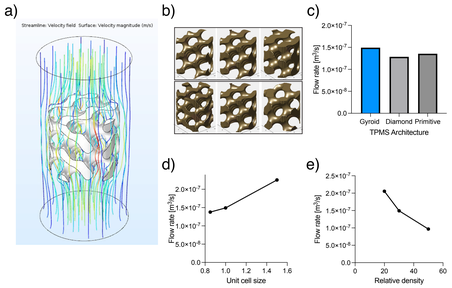


Figure 2. (a) Simulation showing fluid velocity through a lattice. (b) TPMS (Triply Periodic Minimal Surface) geometries with increasing relative density (top) and unit cell size (bottom). (c,d,e) Outlet flow rate for different TPMS architectures (c), unit cell sizes (d), and relative densities (e).

Mechanical tensile testing

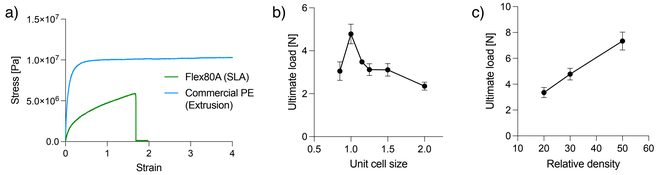


Figure 3. Tensile test results for (a) polyethylene and Flex 80A, (b) Flex 80A TPMS Gyroid with varying unit cell sizes, and (c) Flex 80A TPMS Gyroid with varying relative densities. Unit cell size 1 and relative density 50 exhibit the highest mechanical strength.

Hydrophilicity assessment

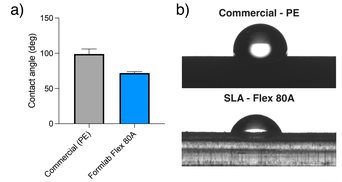


Figure 4. Contact angle measurement of polyethylene (PE) and Flex 80A; (a) numerical result, (b) images. Flex 80A is more hydrophilic than PE.

Leaching test

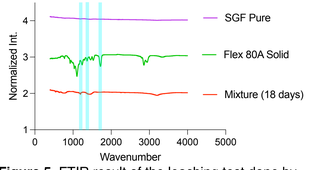


Figure 5. FTIR result of the leaching test done by submerging Flex 80A solid in simulated gastric fluid for 18 days shows no significant material degradation.

CONCLUSION

- The computational model highlights extraluminal flow dominance in most cases, leading to an optimized design prioritizing extraluminal flow. Abscess size and shape minimally impacted initial flow rate (< 3%).
- Our novel 3D-printed lattice stent achieved a two-fold increase in initial flow rate compared to a commercial stent of identical dimensions, tested on a benchtop abscess drainage model.

FUTURE DIRECTION



- Conduct comprehensive material testing to ensure bioinertness in vivo.
- Preclinical efficacy testing
- Explore other applications in abscess drainage.

Brought to you by M42