Traction of Helical Soft Continuum Actuators for Endoluminal Robots

Gillian McDonald, Amer Safdari, and Timothy M. Kowalewski, PhD

Medical Robotics and Devices Lab

University of Minnesota
Driven to Discover℠

Motivation

Background

Soft robots promise new types of endovascular access currently unattainable for traditional surgical robots. This includes novel locomotion through blood vessels as suggested in [1] and endovascular abdominal aortic aneurysm repair (EVAAR) which requires anchoring guidewires. Current methods (Fig. 1) include guidewires with curved ends that provide poor anchoring [2] or balloon anchors which block blood flow [3]. We propose soft, catheter-deployed, continuum spiral actuators inflated with saline to provide safe, compliant anchoring without blocking blood flow (Fig. 1 III). Specifically, we evaluate the traction forces of such spiral actuators as a function of typical intravascular actuation pressures compared to a control of a balloon actuator.

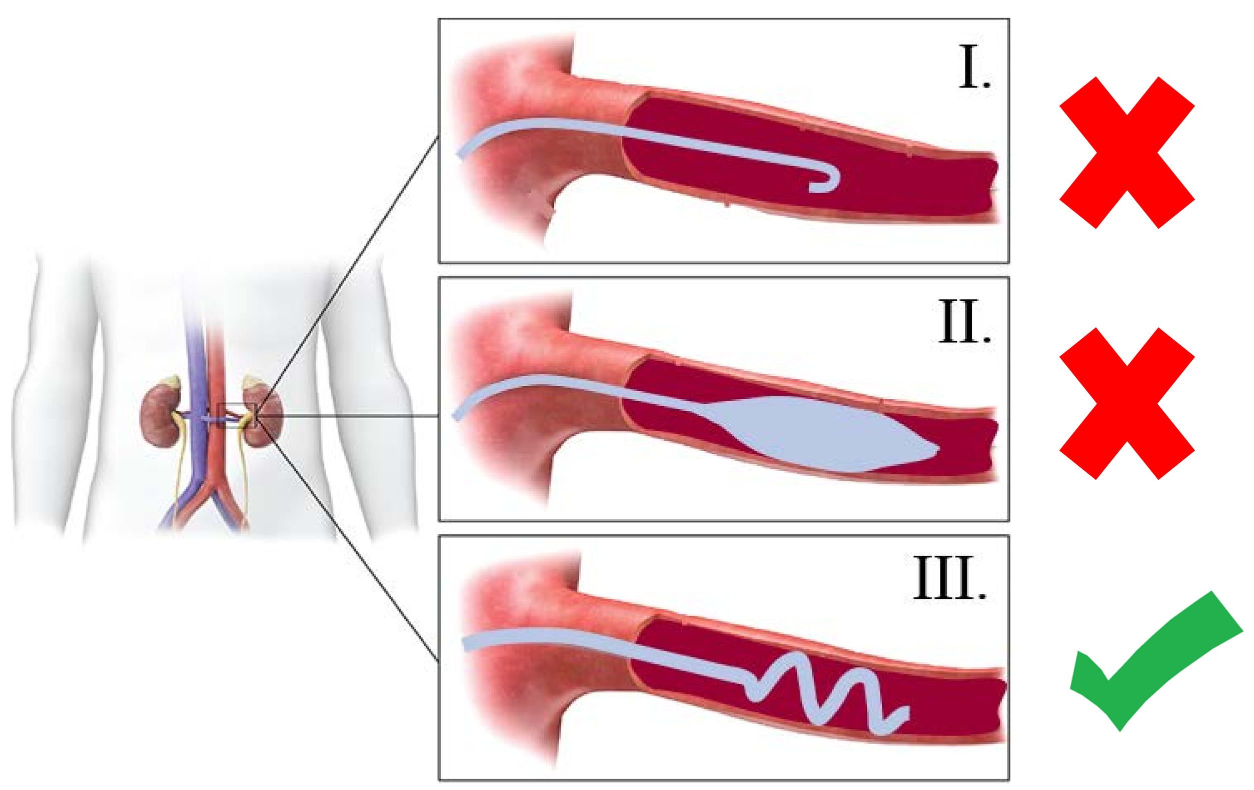

FIGURE 1: Guidewire with anchoring method of: **I.** curved end, **II.** balloon, **III.** our continuum helical actuator.

References and Acknowledgments

[1] M. D. Gilbertson, G. McDonald, G. Korinek, J. D. Van de Ven, and T. M. Kowalewski, "Serially actuated locomotion for soft robots in tube-like environments," IEEE Robotics and Automation Letters, vol. 2, no. 2, pp. 1140–1147, 2017.
[2] T. O. McNamara, B. A. Kirts, and E. J. Morris, "Preformed wire guide," Jul. 3 2001, united States Patent 6,254,550.
[3] M. H. Rosner and M. D. Okusa, "Acute kidney injury associated with cardiac surgery," Clin J Am Soc Nephrol, vol. 1, no. 1, pp. 19–32, 2006.
[4] J. Bishop-Moser and S. Kota, "Towards snake-like soft robots: Design of fluidic fiber-reinforced elastomeric helical manipulators," Proc. IEEE/RSJ Int. Conf. Intell. Robots and Syst. (IROS), pp. 5021–5026, Nov 2013.

Acknowledgments

This work was supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. 00039202.

Methods

Experimental Setup

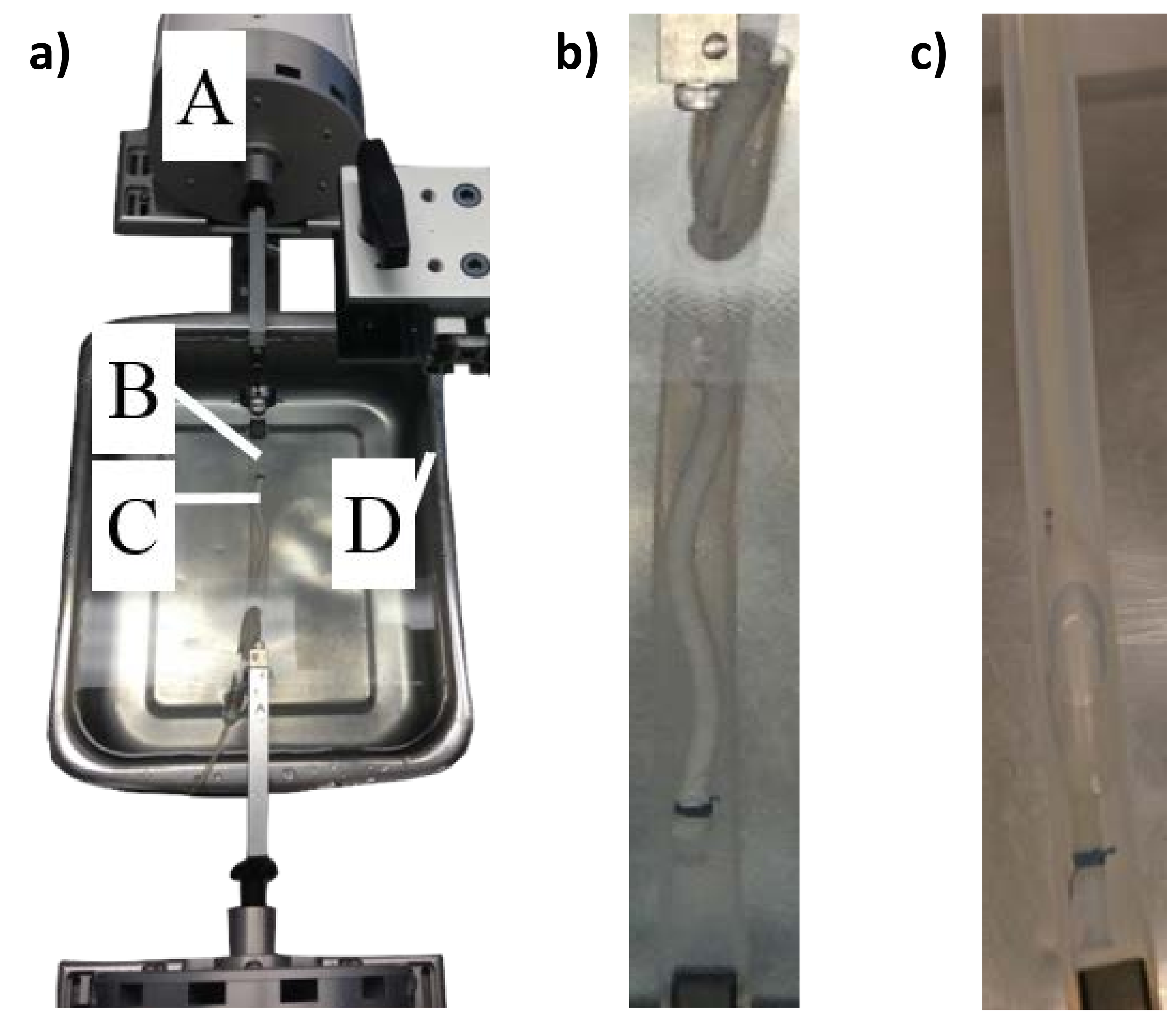

FIGURE 2: a) Experimental setup: A. ElectroForce TestBench B. surrogate artery C. anchored helical actuator D. water bath; **b)** Helical actuator in surrogate artery; **c)** Control balloon.

Methods

- Helical actuators (FREEs, [4], Fig. 3) were designed to anchor into a surrogate artery with 12.7 mm ID.
- A 4.76 mm OD, unwrapped latex tube was used as an experimental control of a traditional balloon (Fig. 1 II).
- Traction forces were measured in a water bath using an ElectroForce TestBench (Fig. 2a) with a 20 mm stroke length at a velocity of 0.2 mm/s (1mN accuracy).
- Actuators were inflated to a specified pressure inside the surrogate artery, then pulled apart.
- Pressure was increased by 0.5 atm until actuator burst.

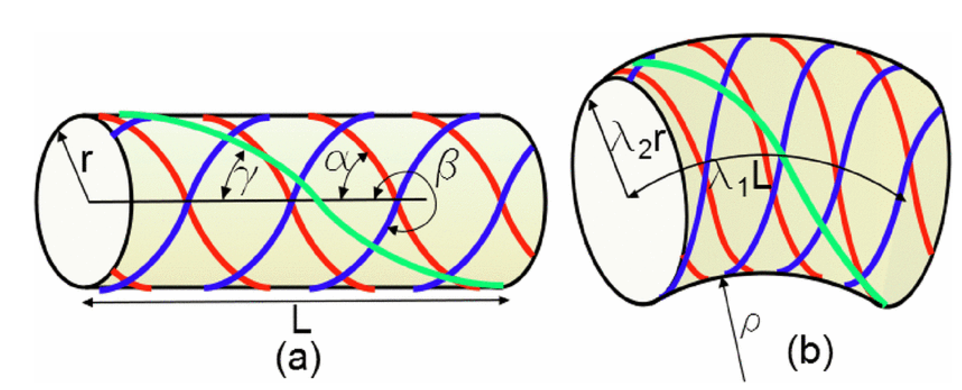

FIGURE 3: a) FREE actuator where α, β, and γ represent the wrap angles of each of the three fibers **b)** FREE where λ_1, λ_2, ρ, and L represent the axial stretch, radial stretch, radius of curvature, and overall length, respectively [4].

Results and Conclusion

Results

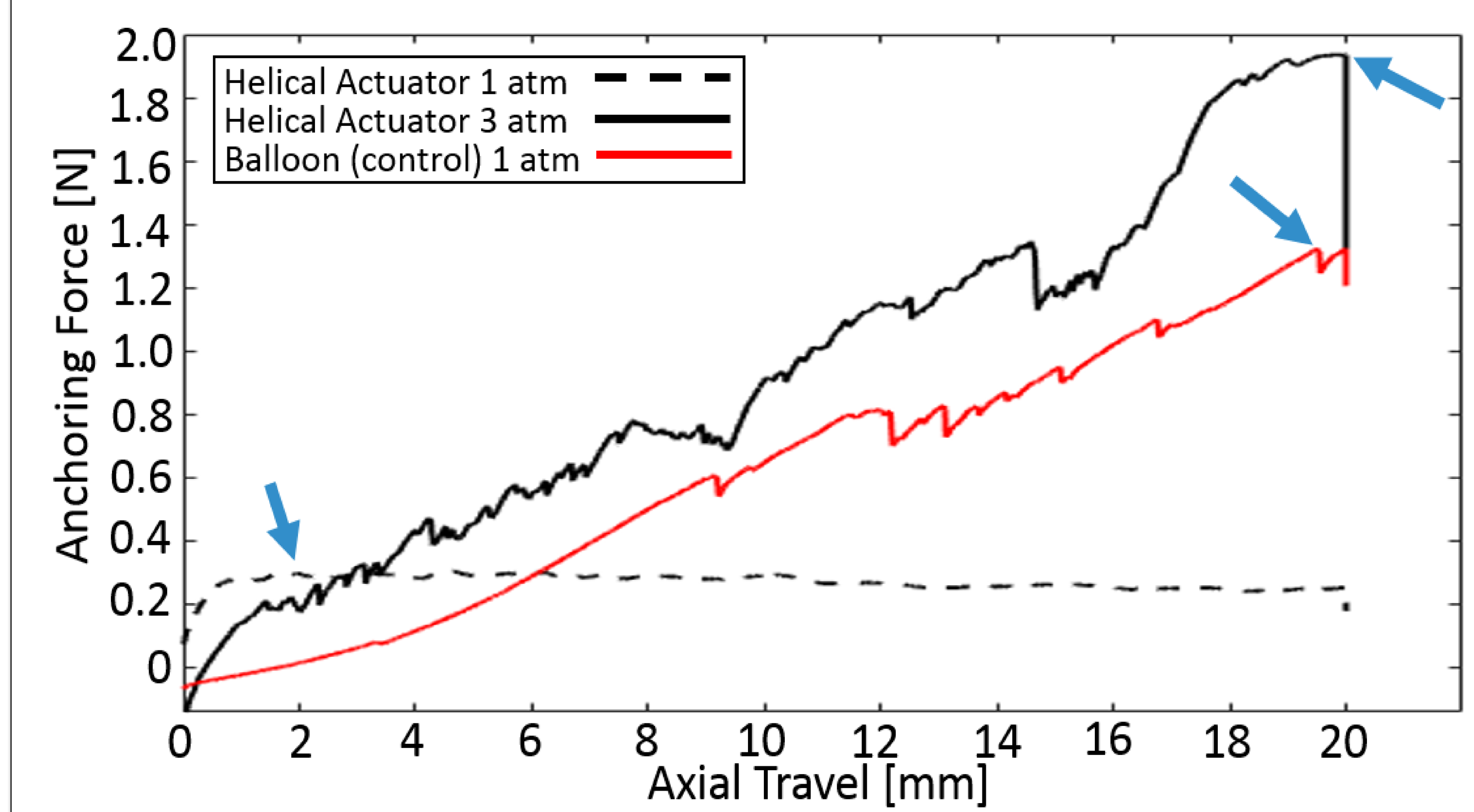

FIGURE 4: Representative transient data showing peak anchoring forces.

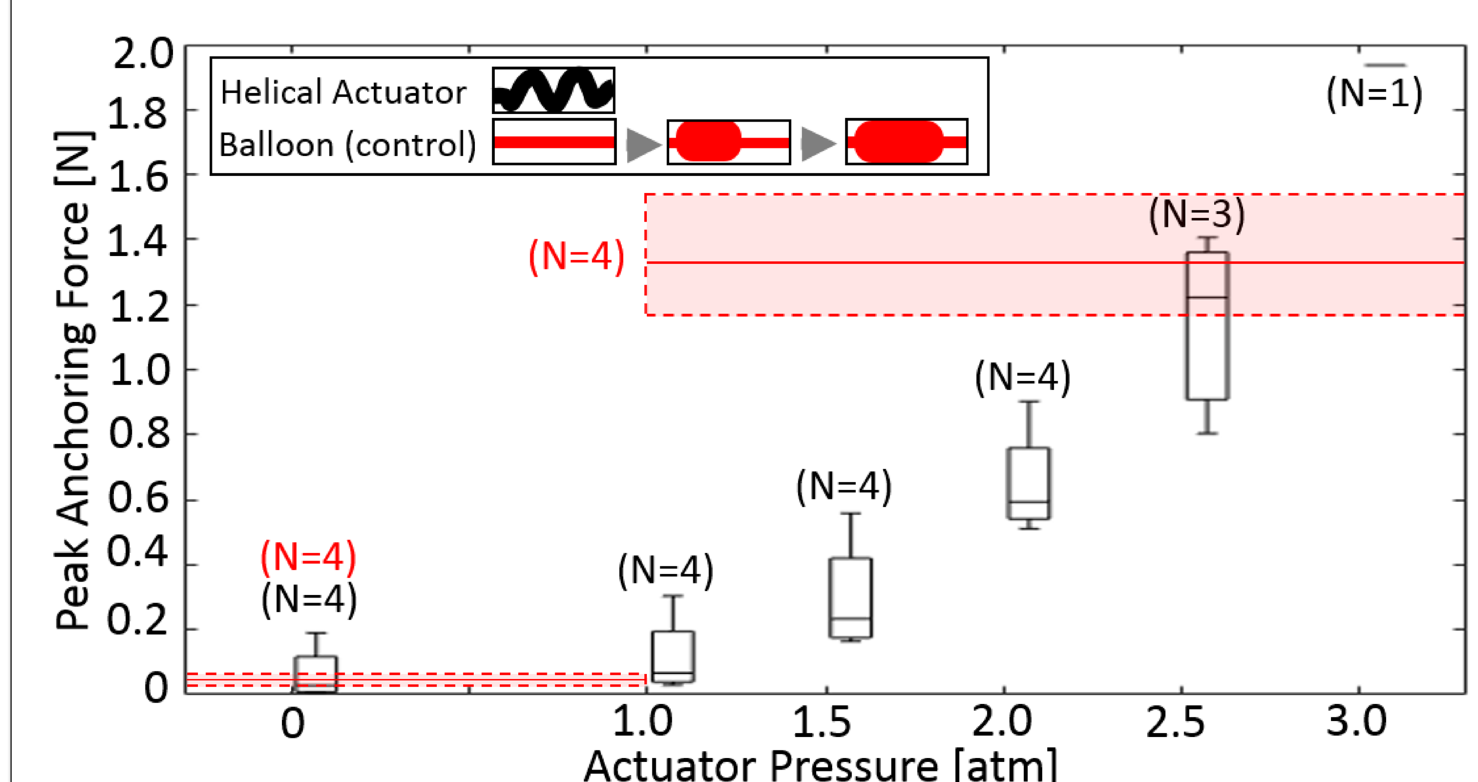

FIGURE 5: Peak actuator anchoring force. Once ballooning occurred, the overall length of the control balloon was maintained at 25 mm at a pressure of 1 atm. The engaged surface areas of the helical actuator and control balloon were 10.47 cm^2 and 20.27 cm^2, respectively.

Conclusion

- The results show that our helical actuator was capable of achieving comparable anchoring performance to the control balloon, yet did so with less engaged surface area and without occluding the surrogate artery (Fig. 5).
- Future work will include ex-vivo studies in porcine and human arteries, as well as an expansion into soft robot locomotion in tube-like environments.