A Dedicated Venous Stent for May-Thurner Syndrome

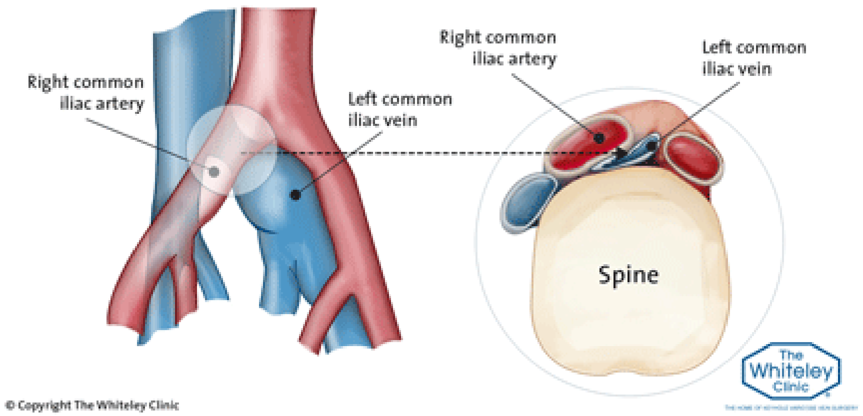
L. Biernacki, E. DiMartini, A. Magnotta, C. Wood

Advisor: C.T. Wagner, Ph.D.

THE COLLEGE OF NEW JERSEY

Introduction

- May-Thurner Syndrome (MTS)
  - Iliac vein is compressed between the iliac artery and lumbar vertebrae
- The mechanical compression and chronic pulsation damage the vein and lead to impaired venous return [1]



- MTS patients are at high risk for the development of deep vein thrombosis (DVT) [2,3]
  - Symptoms include blood pooling, pain, tenderness, edema, and skin discoloration in the legs

[1] Omar, Al-Nouri, MD, and Ross Milner, MD. "May-Thurner Syndrome." May-Thurner Syndrome | Vascular Disease Management.
[2] Duerig, T., & Wholey, M. (2002). A comparison of balloon- and self-expanding stents. Minimally Invasive Therapy & Allied Technologies, 11(4), 173-178.
[3]Oguzkurt L, Ozkan U, Tercan F, Koc Z. Ultrasonographic diagnosis of iliac vein compression (May-Thurner) syndrome. Diag Interv Radiol 2007;13:152–155.
Image: "Intravascular Ultrasound (IVUS) - The Whiteley Clinic." *The Whiteley Clinic*.

Product Need

This project aims to design a device to mitigate symptoms and improve options available for treatment of MTS

- Around 200,000 cases of MTS diagnosed annually [4]
- No dedicated venous stents are approved for specific use in the iliac vein [5]
- Veins have thinner walls, lower flow profiles, and are larger in size
- Approved arterial stents are currently used, but do not address all needs

Current Treatment Options

Commercial Stent Name	Patency	Radial Force	No Foreshortening	Size	Dedicated Venous	Flexibility
WALLSTENT	✓			✓		
Sinus XL			✓			
Veniti Vici		✓			✓	✓
Protégé			✓		✓	

[4] Shebel, Nancy D., and Chyrle C. Whalen. "Diagnosis and Management of Iliac Vein Compression Syndrome." Journal of Vascular Nursing 23.1 (2005): 10-17.
[5] "Endovascular Today - Venous Stenting: Expectations and Reservations." Endovascular Today. July 2015.

Voice of Customers

Customer Need

Mahmood K. Razavi, MD, FSIR , Endovascular Today

"…venous obstructions are stented with what we presume to be suboptimal stents. The development of a new generation of venous stents is an important step in the right direction." [5]

Customer Input

Interventional cardiologist at NY Presbyterian Medical

- Stenting-catheter approach is preferred to invasive surgery
- Balloon expanding stents have the lowest risk for migration
- Stainless Steel is more difficult to compress than other stent materials
- The stent must not perforate the thin venous wall
- Patients with MTS are at higher risk for thrombus formation

[5] "Endovascular Today - Venous Stenting: Expectations and Reservations." Endovascular Today. July 2015.

TCNJ THE COLLEGE OF NEW JERSEY

Design Control

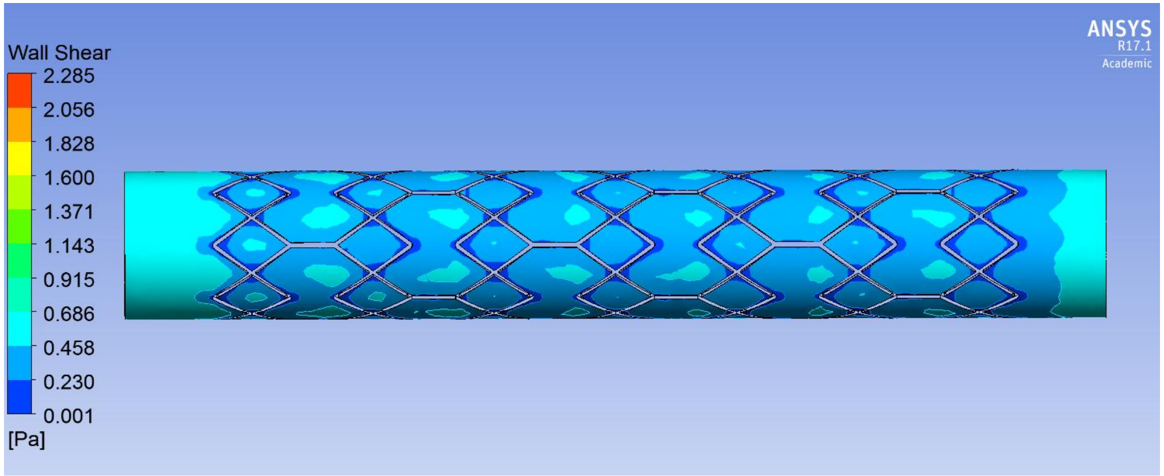
Device Requirements	Specifications
The device must remain patent and resist the force applied by the iliac artery.	Compression less than 50% is classified as patent.[6] Internal stresses may not exceed the compressive strength of stainless steel.
The device must support normal intact endothelial cell layer and function.	Maximum percent stent-endothelium contact area must be $\leq$20% [7]
The device must maintain a clinically relevant placement after deployment.	The stent must remain be within $\leq$5 mm of the intended location in the iliac system.[8]
The product line must be available in discrete sizes to meet surgical need.	16 mm diameter and 90 mm length [9]
The device must maintain proper fluid flow dynamics.	WSS must stay within 1 dynes/cm^2 and 200 dynes/cm^2.[10]
The device must be hemocompatible.	Hemolysis after stent material contacts blood must be less than 5%.[ISO10993-4]

[6] Cho, H., et al. "Stent Compression in Iliac Vein Compression Syndrome Associated with Acute Ilio-Femoral Deep Vein Thrombosis." Korean Journal of Radiology 16.4 (2015): 723.
[7] Károly, Dóra, Miksa Kovács, Andrew Terdik Attila, and Eszter Bognár. "Investigation of Metallic Surface Area of Coronary Stents." Biomech Hung Biomechanica Hungarica (2013)
[8] Chen, H. Y., A. K. Sinha, et al. "Mis-sizing of Stent Promotes Intimal Hyperplasia: Impact of Endothelial Shear and Intramural Stress." AJP: Heart and Circulatory Physiology 301.6 (2011).
[9] Marston, William A., Abha Chinubhai, Stephen Kao, Corey Kalbaugh, and Ana Kouri. "In vivo Evaluation of Safety and Performance of a Nitinol Venous Stent in an Ovine Iliac Venous Model." Journal of Vascular Surgery: Venous and Lymphatic Disorders 4.1 (2016): 73-79.
[10] Goel, M. S. "Adhesion of Normal Erythrocytes at Depressed Venous Shear Rates to Activated Neutrophils, Activated Platelets, and Fibrin Polymerized from Plasma." Blood 100.10 (2002): 3797-803.
[ISO10993-4] ISO/IEC stage 10993-4: Biological evaluation of medical devices -- Part 4: Selection of tests for interactions with blood, 2002-10-01, International Organization for Standardization, Geneva, Switzerland.

Verification Testing

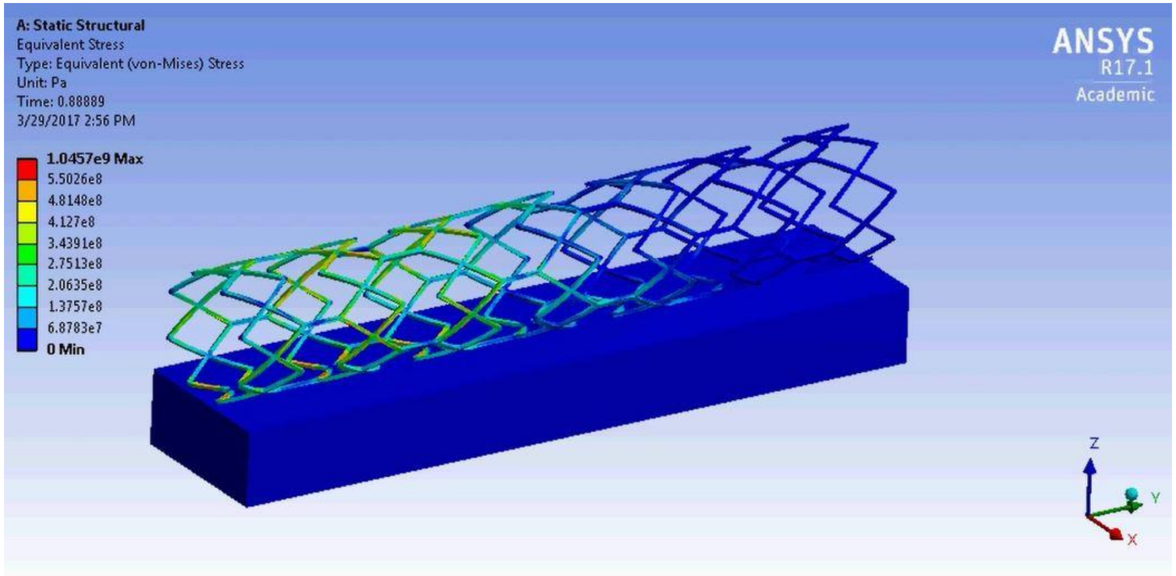
Flow Simulations:

Wall shear stress (WSS) must be within 1-200 dyne/cm^2



Mechanical Simulations:

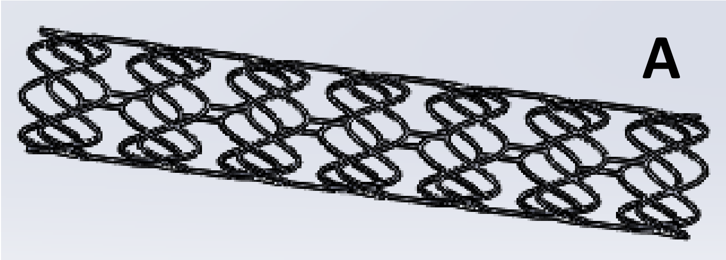
Internal stress must not exceed ultimate strength of stainless steel

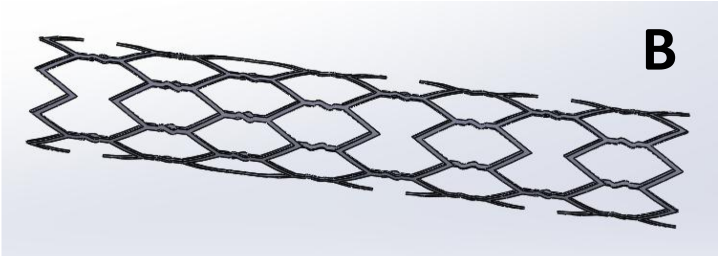


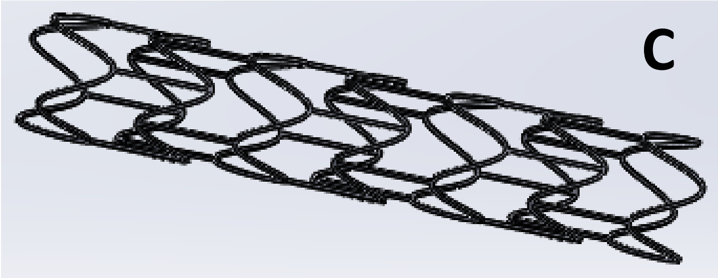
SolidWorks 2015 with GW3D Add-In for design and ANSYS 17.1 for mechanical and flow testing

Optimization

	A	B	C
% WSS < 0.1 Pa	17	6	27
% Internal Stress > 550 MPa	1.6	3.6	18.7
Perforation Risk	Low	High	Low
	PASS	**PASS**	**FAIL**





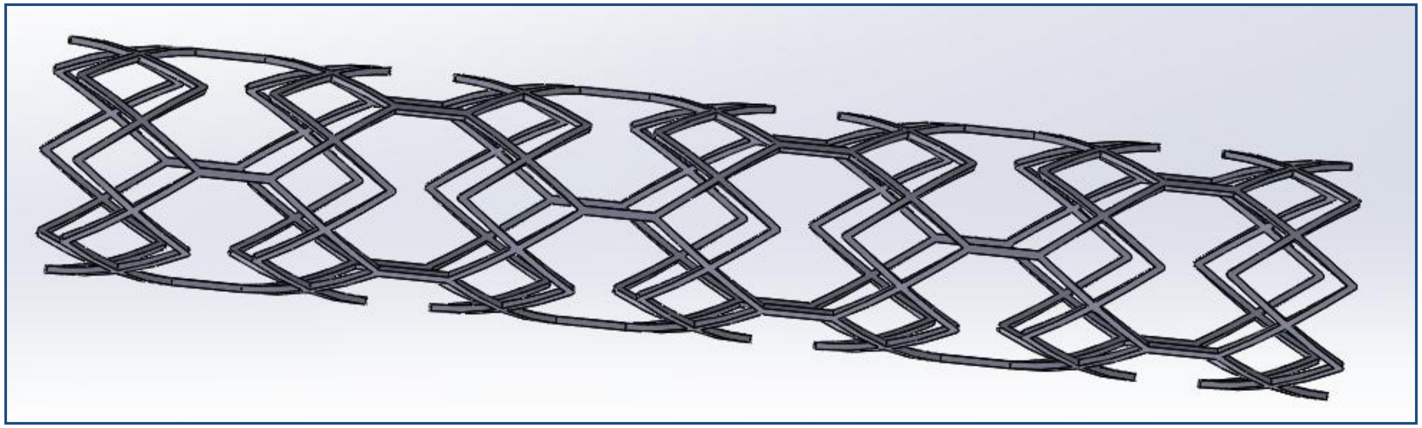


Parameters to Optimize

- Ring Shape
- Ring Size
- Connection Shape
- Connection Length
- Number of Connections
- Thickness
- Width

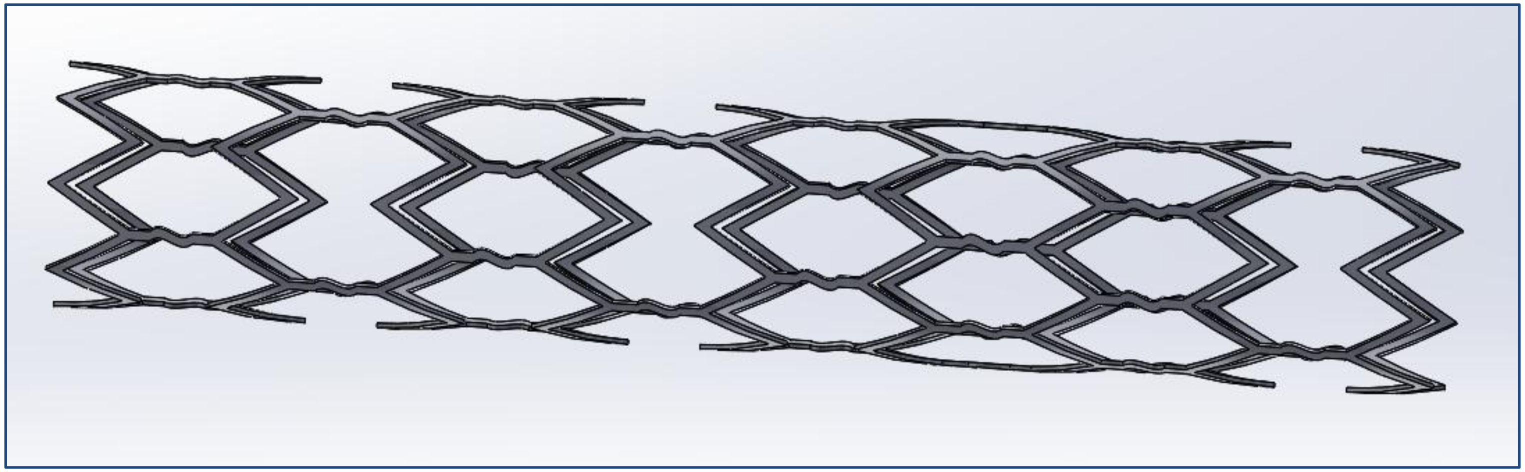
Final Design

- To determine which design best meets the device specifications, a unique scoring system was developed
- This stainless steel stent is optimal because:
  - Only 7.5% of wall shear stress below 0.1 Pa
  - Only 1.45% internal stresses above 550 MPa
  - 13.8% Surface Area
  - 16 mm diameter and 90 mm length
  - Filleted edges to minimize vessel damage
  - Less rigid than other designs



Future Tests

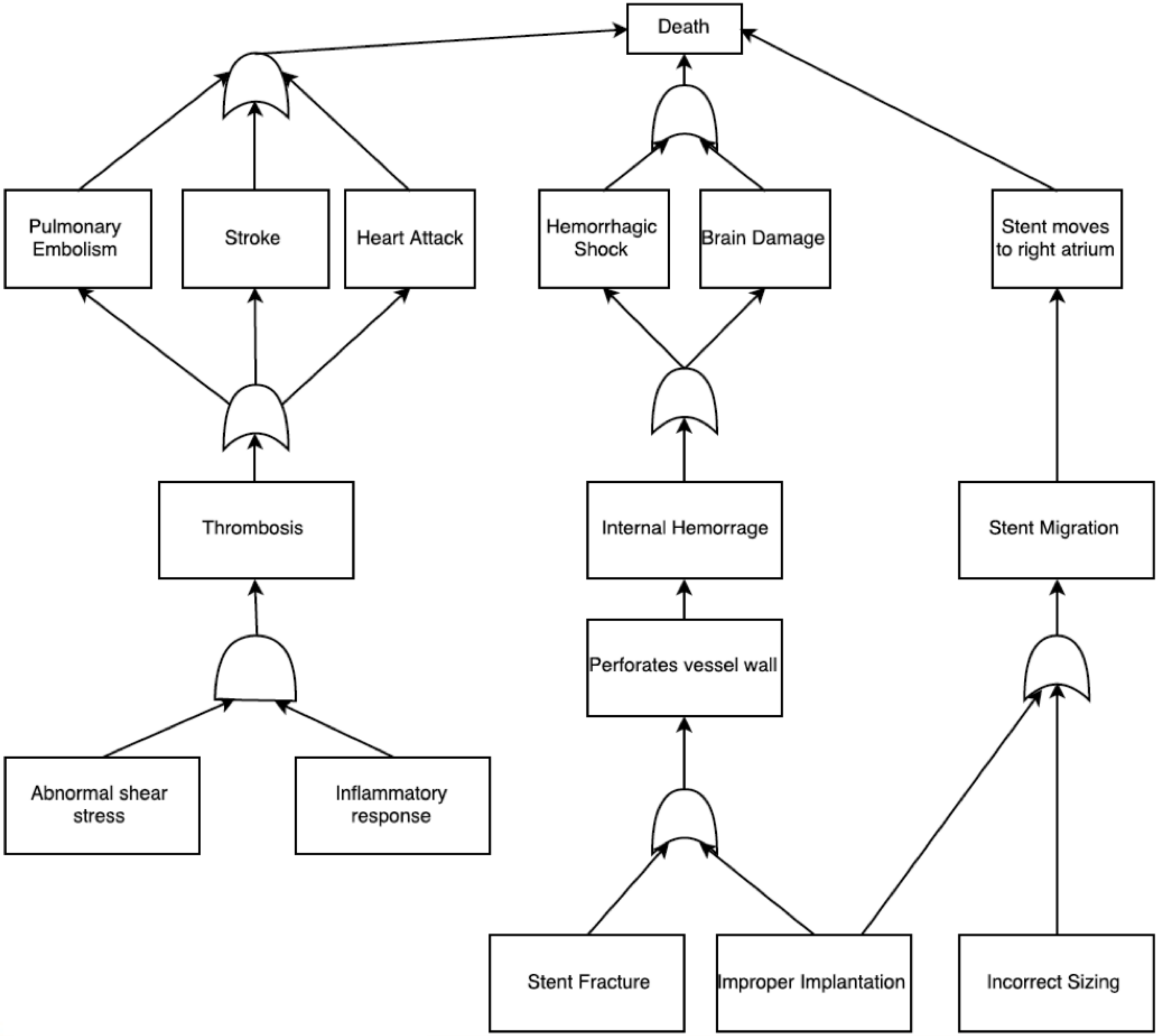
- Ongoing verification testing to further optimize the final stent design
  - Continuation of mechanical and flow simulations
  - Flow loop for migration verification
  - In vitro hemolysis assay using spectrophotometry



Commercialization

- Provisional patent for the final stent design
- Class III Medical Device requiring clinical studies
- Partner with stent manufacturing companies having experience with balloon-catheter delivery systems (eg Cordis, Boston Scientific, Edwards)
  - Animal studies
  - IDE application and clinical studies
  - PMA application

Risk Assessment



Mitigation Methods

- Anticoagulants reduce the risk of thrombosis
- Radiopaque markers and surgical instruction to mitigate migration
- Sizing instructions to reduce risk of oversizing to minimize bleeding