Developing a Y-Shaped Cutting Device Toward Experimentally Determining Cutting Properties of Blood Clots

MECHANICAL ENGINEERING
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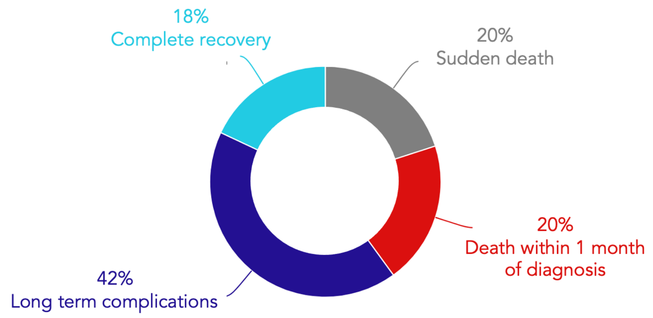
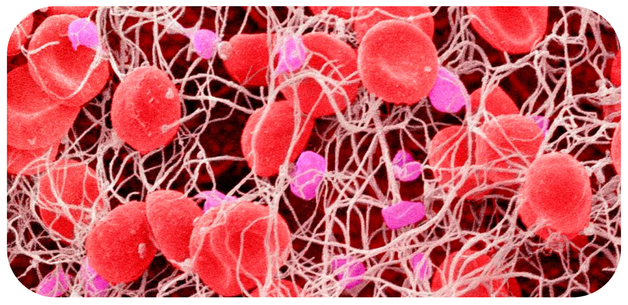
Blood Clot Complexity Limits Treatment

The best venous thrombectomy devices have success rates of under 50% [1]

Advancing clot-removal techniques and technologies requires a deeper understanding of their material properties

300,000 — 600,000 people experience venous thromboembolisms each year in the US [2]



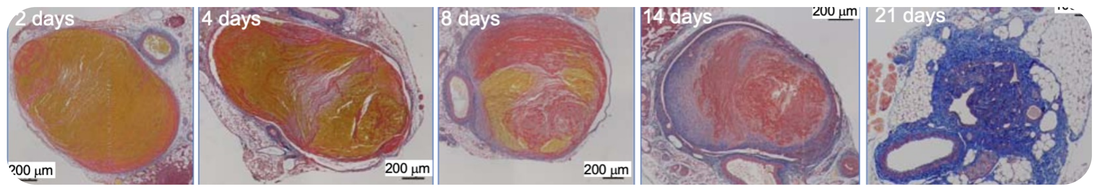


Blood clot SEM image by Susumu Nishinaga

Venous Clot Composition

- Red Blood Cells
- Platelets
- Fibrin
- Collagen

Blood clot properties and composition vary based on the context in which they are formed

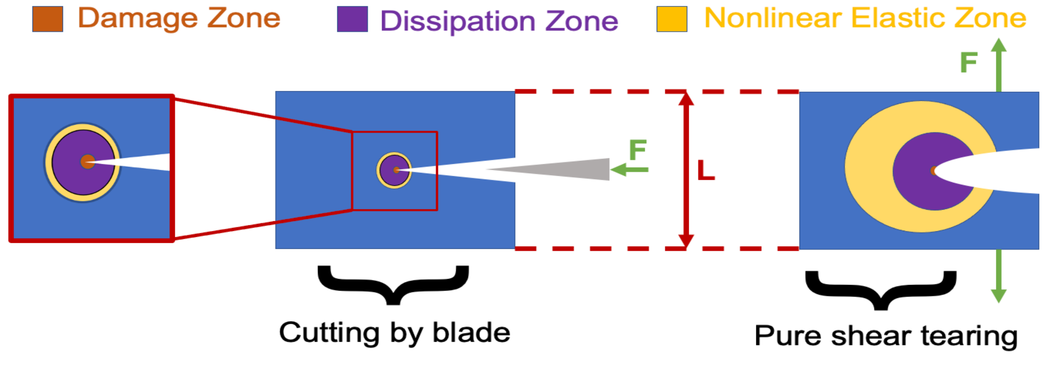


Blood clot cross section images by Dr. Andrea Obi. Shows the aging of a blood clot in 21 days, stain colors represent: Yellow: red blood cells, Red: fibrin, and Blue: collagen.

Tool-based fracture could permit clot breakup while minimizing embolization, but *fracture properties of clots remain unknown.*

Cutting ≠ Tearing in Fracture Mechanics

Cutting has been proven as a more controlled and precise type of fracture than tearing, so it will be the main subject of this research

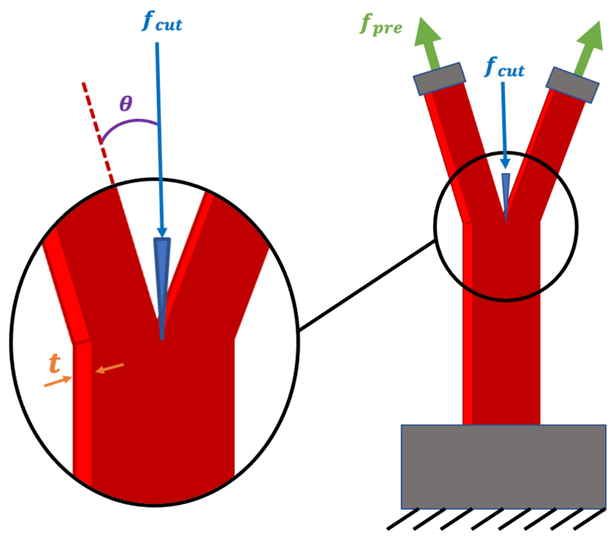


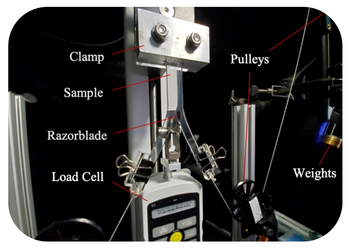
The difference between cutting and tearing, adapted from Zhang 2021

Y-Shaped Test Characterizes Cutting

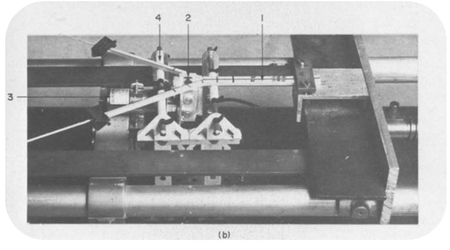
Y-Shaped cutting (YSC) involves a blade that cuts through a sample

Tension is applied to the material (f_{leg}) and the force of the blade (f_{cut}) is measured in the experiment





2021 work at the University of Illinois relating cutting and tearing in silicone elastomers



Lake and Yeoh first used YSC in 1978 to determine the cutting resistance of rubber

YSC tells us the energy to cut a soft material, G_{cut}

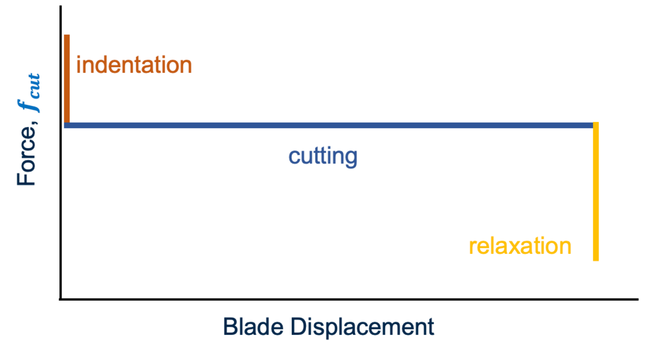
Load on the sample legs; Average pre-stretch of the sample legs; Cutting force

$$G_{CUT} = \frac{2 f_{leg} \bar{\lambda}}{t}(1 - \cos\theta) + \frac{2 f_{cut} \bar{\lambda}}{t}$$

Cutting energy; Sample thickness; Leg angle

Expected Soft Material Cutting Behavior

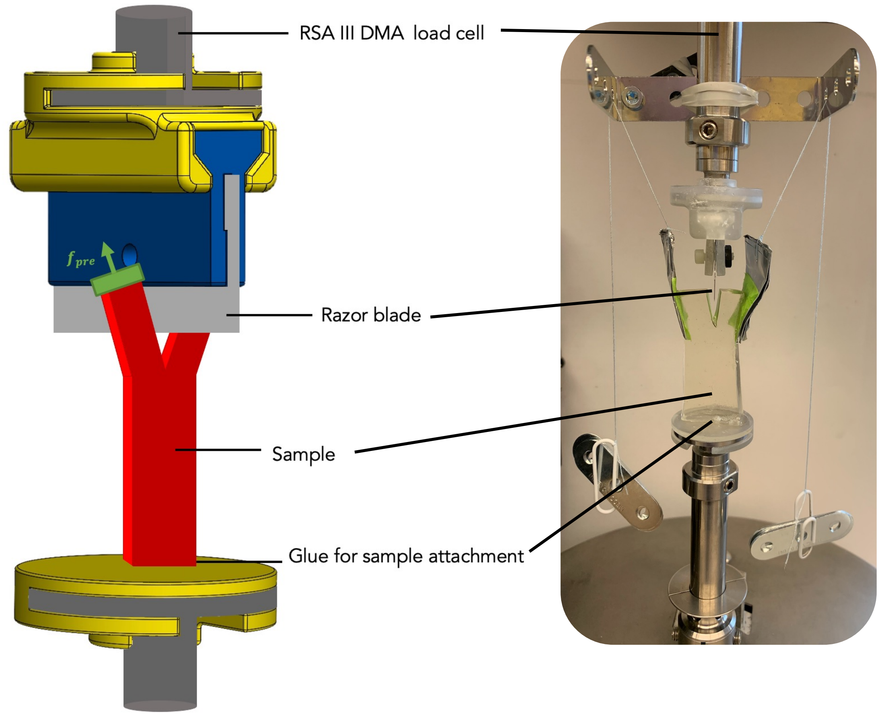
By cutting blood clots of different ages and compositions, the cutting energy needed to fragment them will be determined.



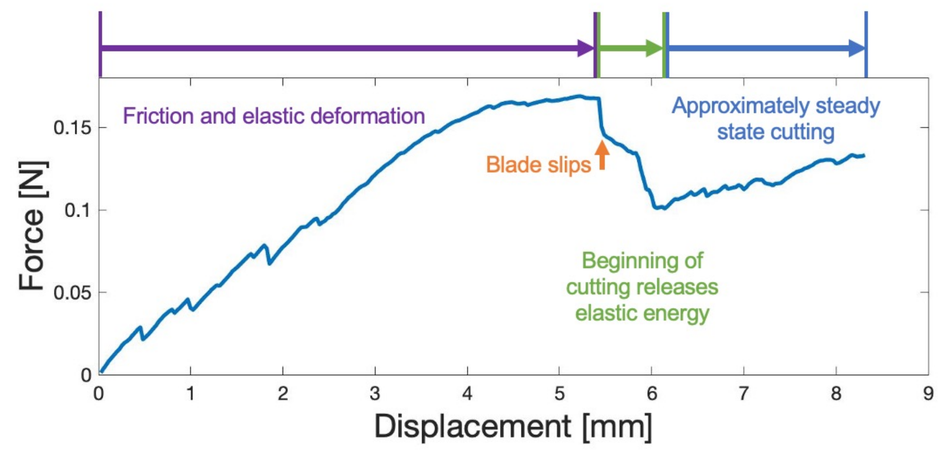
Expected soft material cutting behavior, adapted from Zhang 2021

Experimental Setup

Combining past Y-shaped cutting experimental layouts with expectations of the properties of blood clots, YSC can be optimized for clot-specific operation



YSC For Gelatin Hydrogel



The long-term conclusion of this work will be informing clot models to advance mechanical understanding of clots

Acknowledgements

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References

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