Neuravi
Thromboembolic
Initiative

WLNC
WORLD LIVE NEUROVASCULAR CONFERENCE

Significance of Clot Properties in Mechanical Thrombectomy

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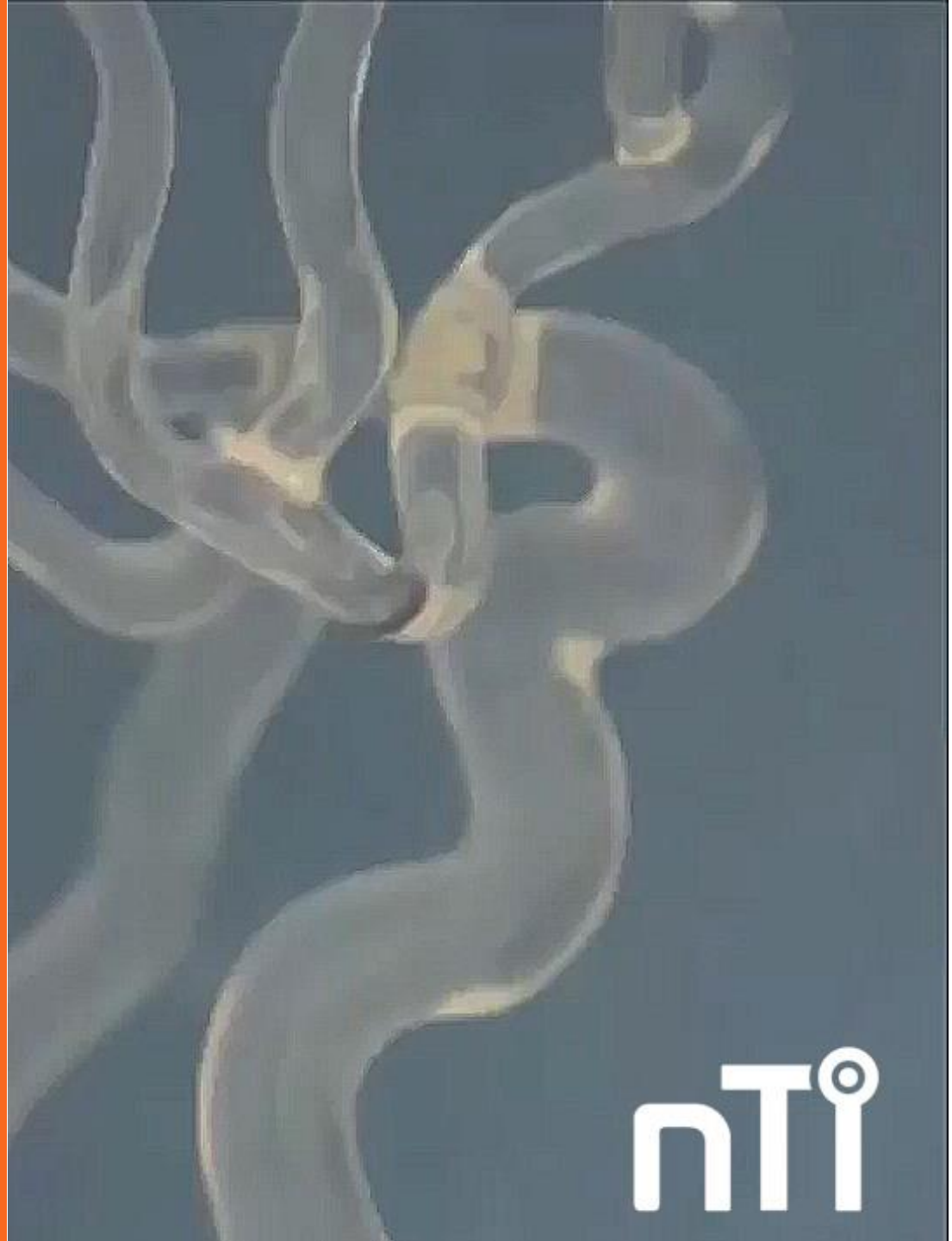
Senior Clinical R&D Engineer,
Neuravi Ltd.

May 16, 2017
WLNC 2017
Los Angeles, California

Disclosures

Employee: Neuravi, a Johnson & Johnson company

Training: Engineering (2006), Medicine (2015)



Soft, cohesive clot

Bifurcation occlusion

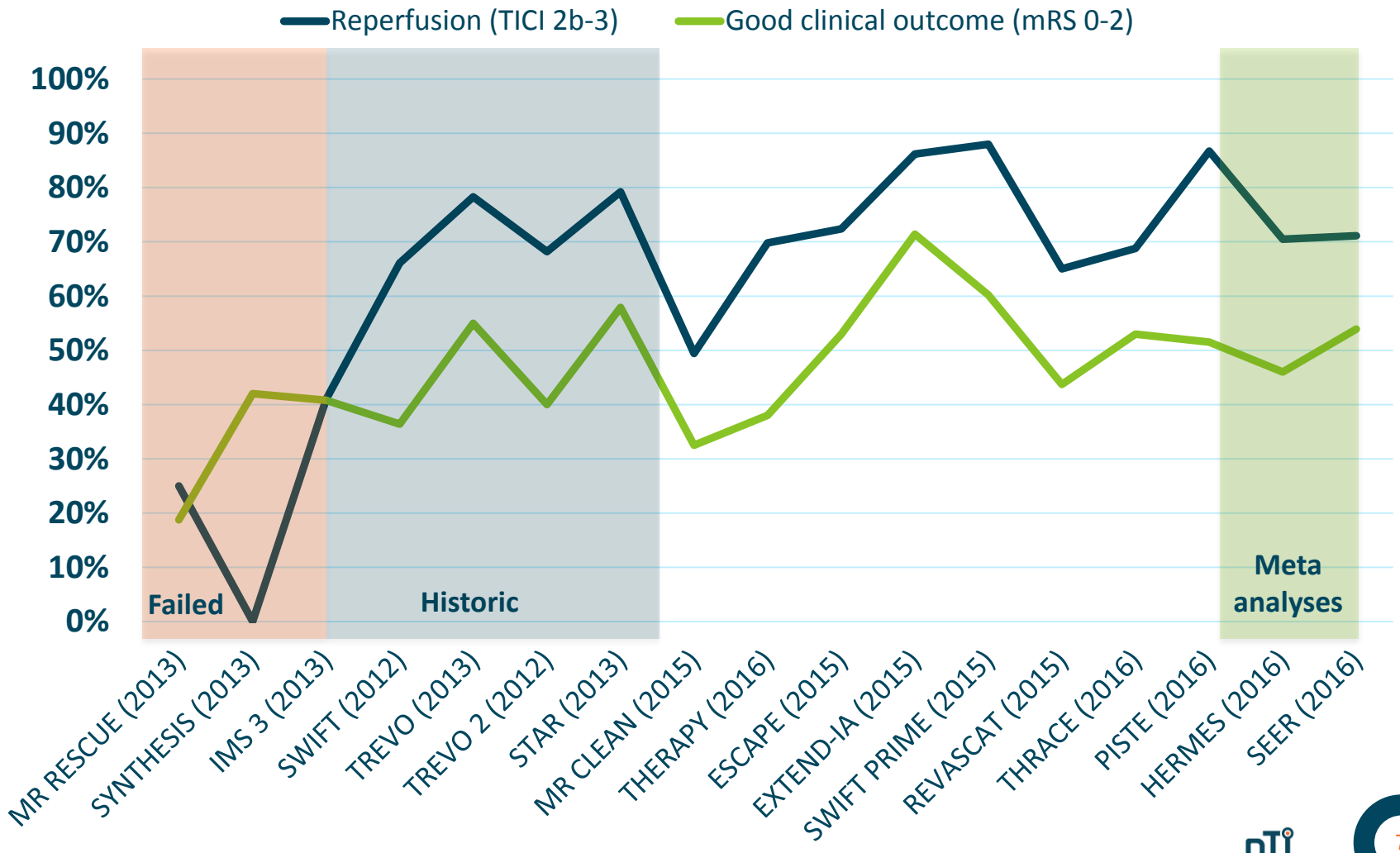
Soft, friable clot

Multiple fragments, bifurcation occlusion

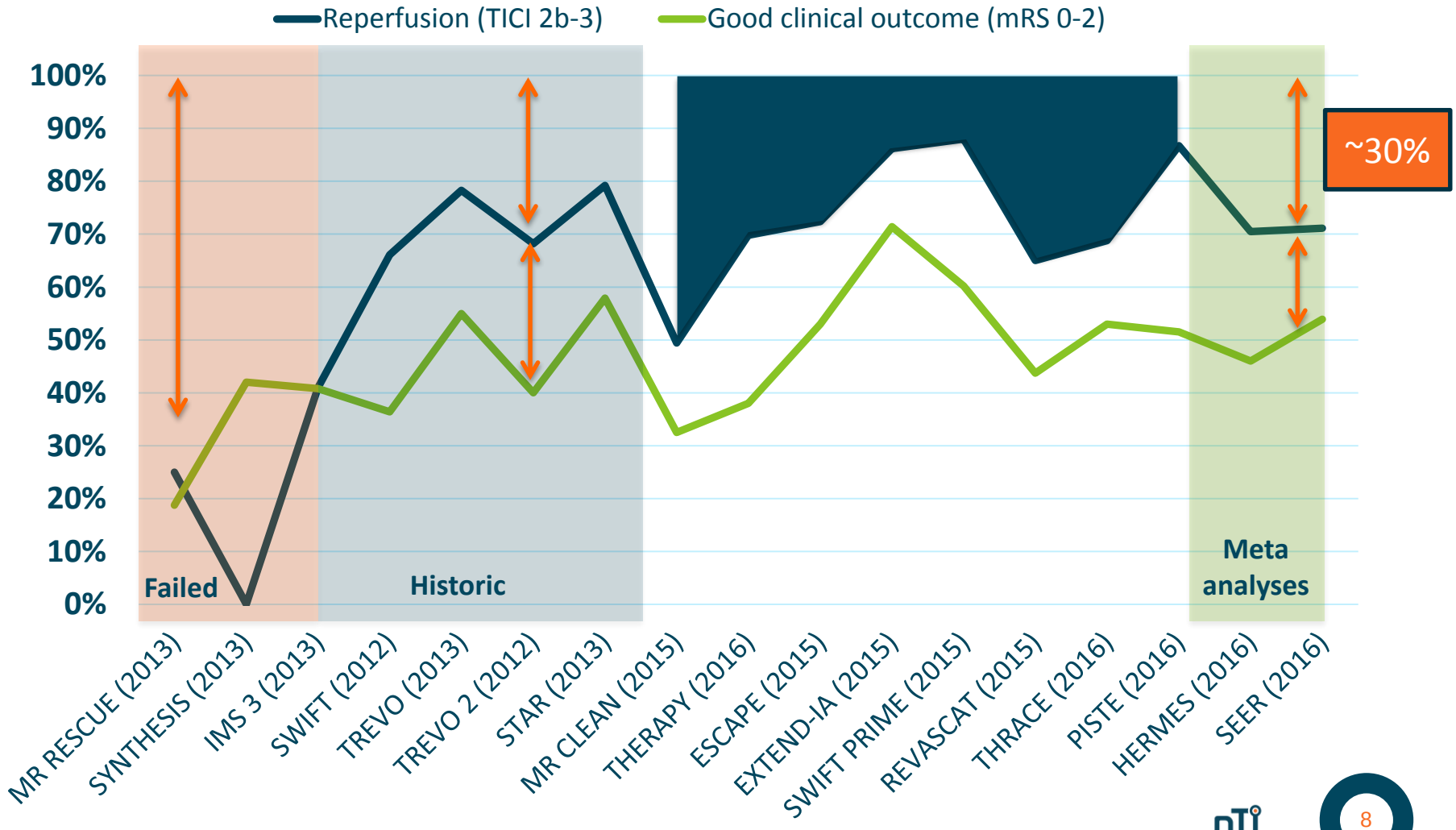
Firm clot

Mid-MCA occlusion

Significant Outcomes Improvement



Significant Room for Outcomes Improvement



Impact of Modified TICI 3 versus Modified TICI 2b Reperfusion Score to Predict Good Outcome following Endovascular Therapy

C. Dargazanli, A. Consoli, M. Barral, J. Labreuche, H. Redjem, G. Ciccio, S. Smajda, J.P. Desilles, G. Taylor, C. Preda, O. Coskun, G. Rodesch, M. Piotin, R. Blanc, and B. Lapergue

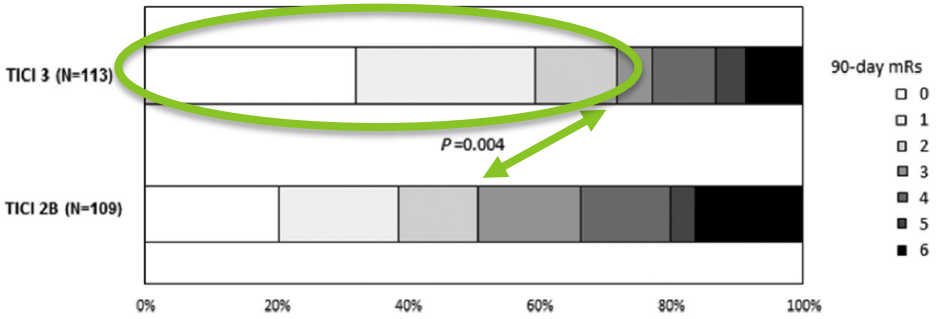
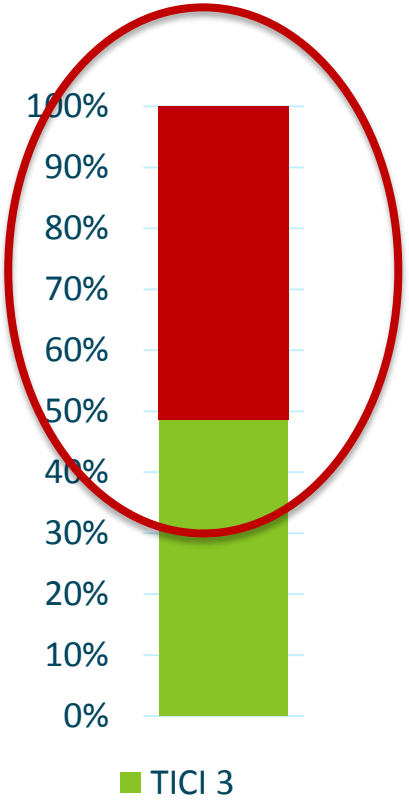


FIG 2. Distribution of modified Rankin Scale scores at 90 days according to successful reperfusion status.

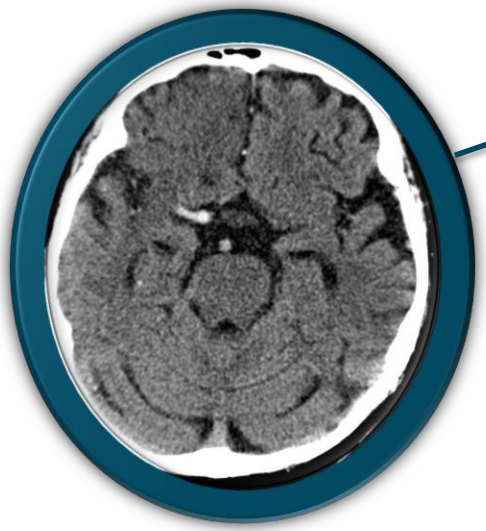
All original thrombectomy publications

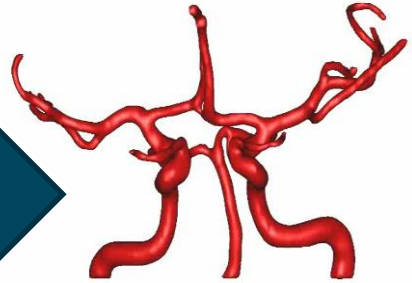
- 2016
- TICI 2b and TICI 3 reported separately
- Retrospective

Author	Single / Multi	Patient Selection	Posterior?	n	TICI 2b-3	TICI 2b	TICI 3	Evaluation
Ishikawa K	Single	All comers	Yes	12	91.70%	58.37%	33.3%	Self
Kashka IN	Single	ICA, M1 only, no tandem	No	34	79%	41.16%	38.2%	Self
Kaesmacher J	Single	Isolated MCA, <=6hrs,	No	239	82.80%	43.05%	39.7%	Indpenedant
Matsumoto H	Single	All comers	No	34	88.20%	44.08%	44.1%	Self
Vargas J	Single	All comers	Yes	191	94.20%	49.70%	44.5%	Blinded
Vargas J	Single	Distal locations only	Yes	35	91.70%	45.99%	45.7%	Blinded
Mascitelli JR	Single	ADAPT intent	No	76	92.10%	43.42%	48.7%	Self
Kuhn AL	Single	Distal locations	Yes	35	97.10%	45.67%	51.4%	Self
Wong JH	Single	RAPID software	Yes	33	93.90%	42.29%	51.6%	Self
Massari F	Single	All comers	Yes	42	97.60%	42.84%	54.8%	Self
Kabbasch C	Multiple	ASPECTS >=5, Sofia catheter, non-consecutive	Yes	30	90%	33.33%	56.7%	Re-evaluated
Wiesmann M	Single	ICA, M1 only, APD technique	No	130	88.50%	23.12%	65.4%	Independent

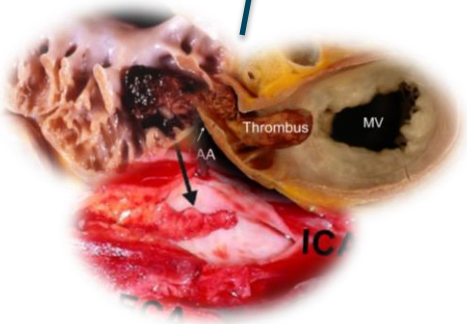


Development Approach: Understand the Problem!



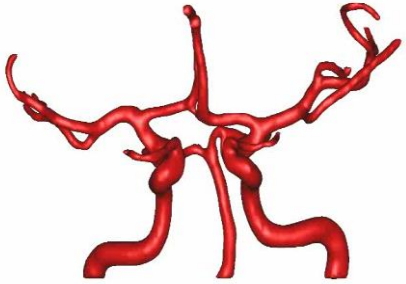


VASCULAR MODEL



CLOT ANALOGS

Development Approach: Understand the Problem!



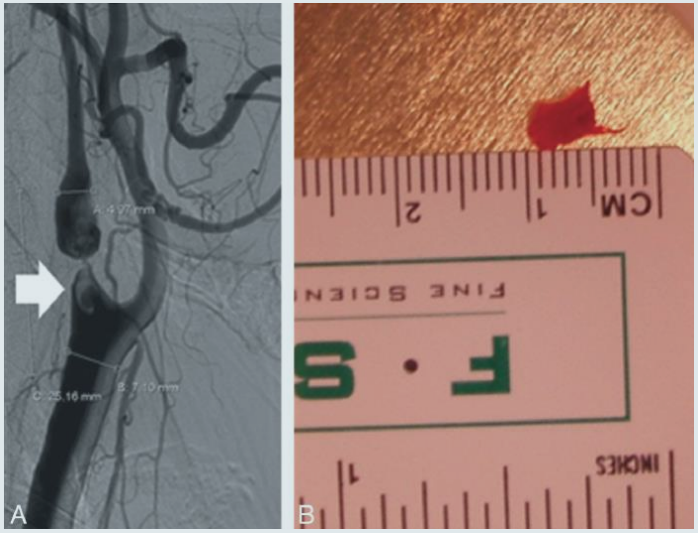
VASCULAR MODEL

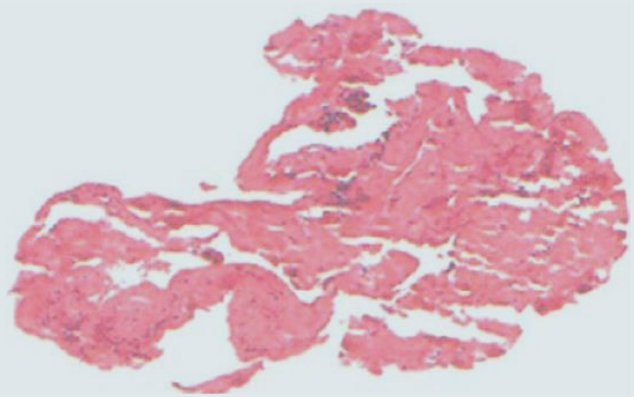
CLOT ANALOGS

emboTrap®

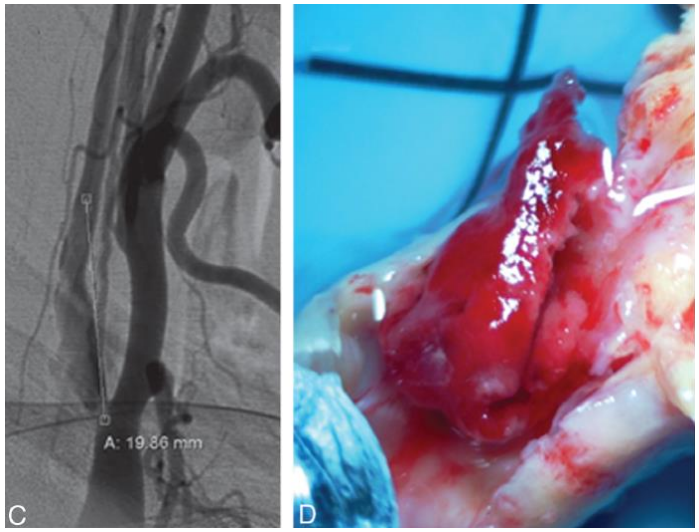
Variation in AIS clots retrieved via thrombectomy

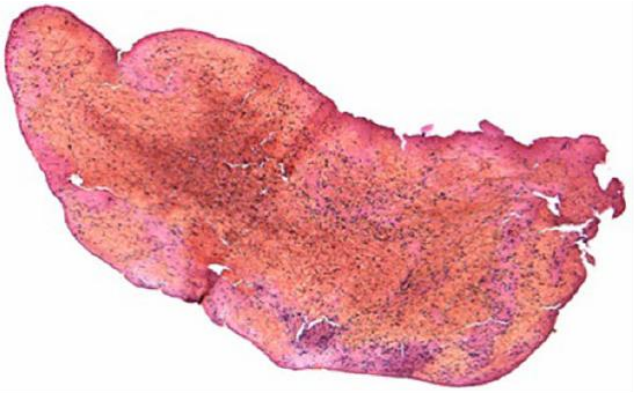
Chueh et al. Mechanical characterization of thromboemboli in acute ischemic stroke and laboratory embolus analogs. AJNR Am J Neuroradiol 2011;32:1237–44.

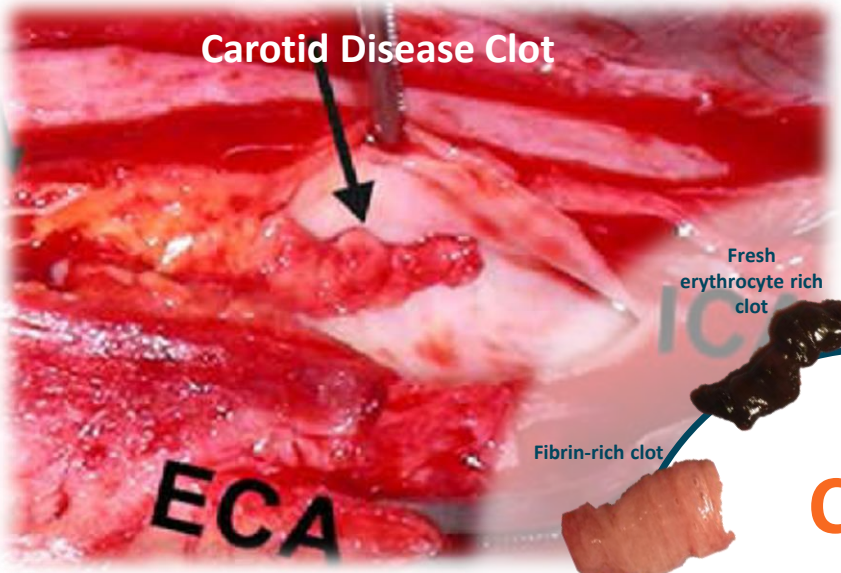


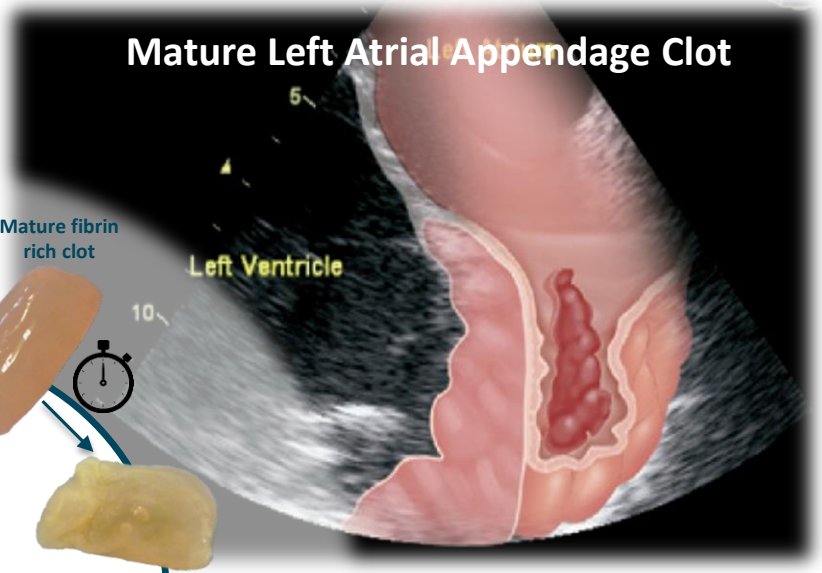


Gasparian et al. Imaging of occlusinve thrombi in acute ischemic stroke. Int J Stroke. 2015 Apr;10(3):298-305









Clot Analogs

Fresh erythrocyte rich clot

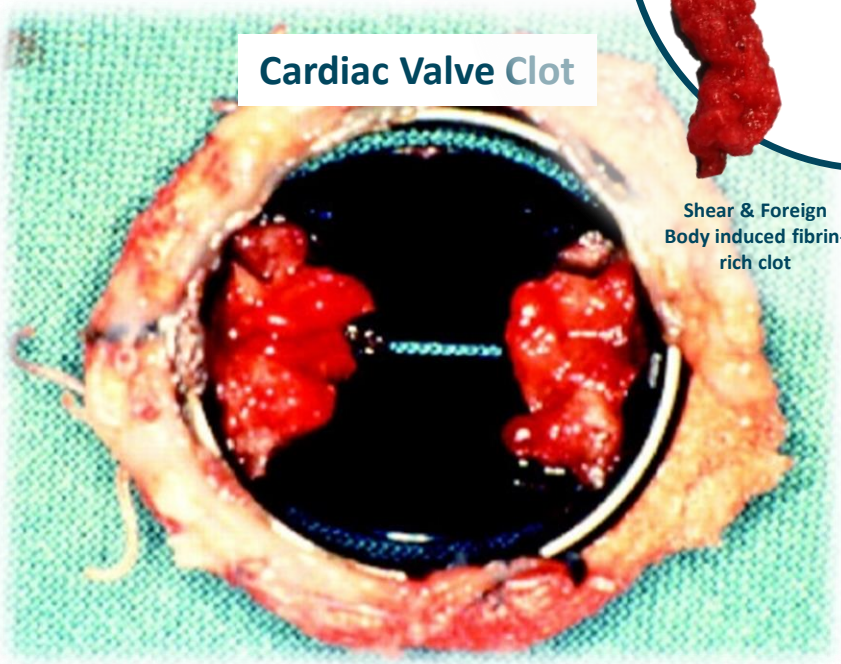
Mature fibrin rich clot

Fibrin-rich clot

Highly organised fibrin-rich clot

Shear & Foreign Body induced fibrin-rich clot

Hybrid clot with mature fibrin base and fresh erythrocyte deposition

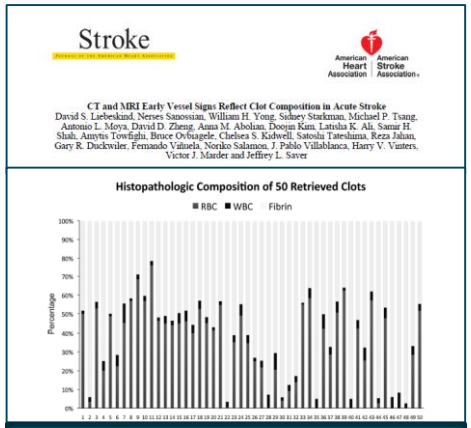


Pisimisis. 2010, Vascular and Endovascular Surgery.

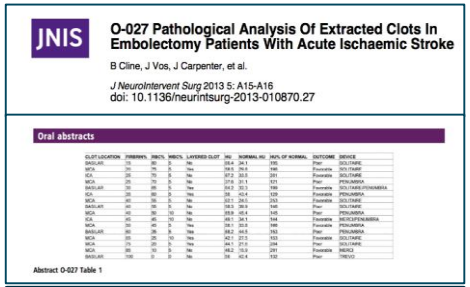
Eleni Doufekias. 2008, Journal of American College of Cardiology.

Kumar: Robbins and Cotran, Pathologic Basis of Disease, 8th Edition.

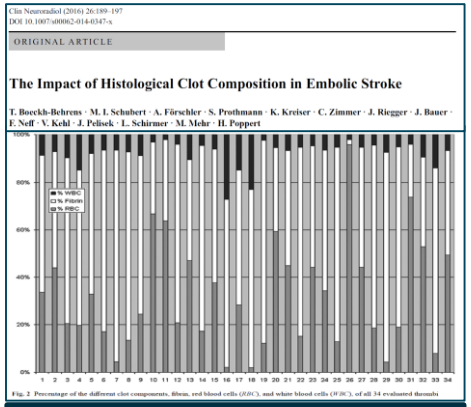
Jun Ogata, 2008, Annals of Neurology



Liebeskind *et al*

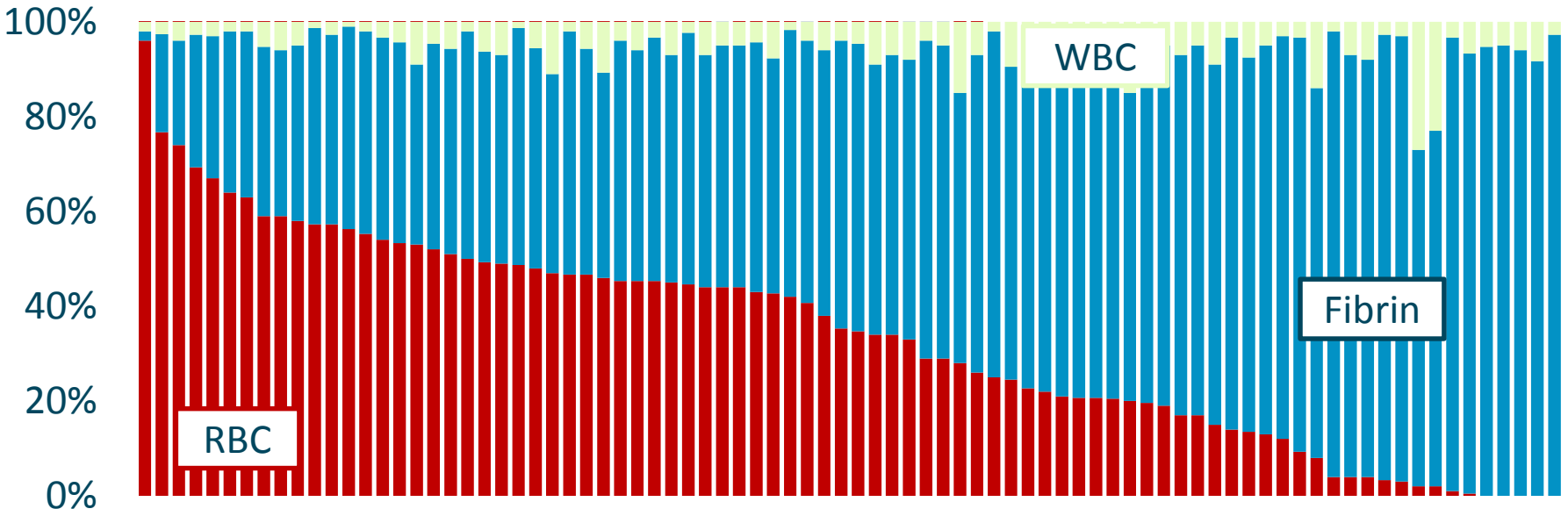


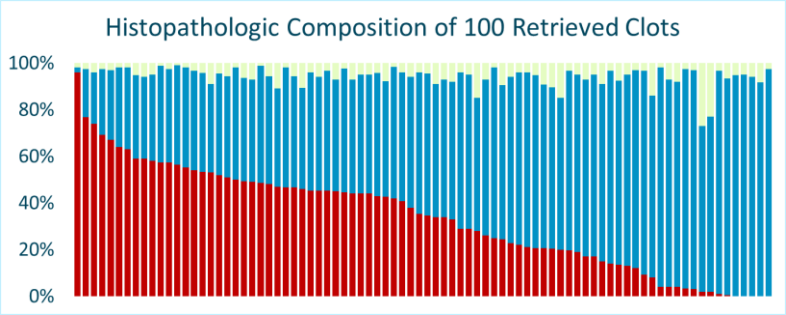
Cline *et al*



Boeckh-Behrens *et al*

Histopathologic Composition of 100 Retrieved Clots

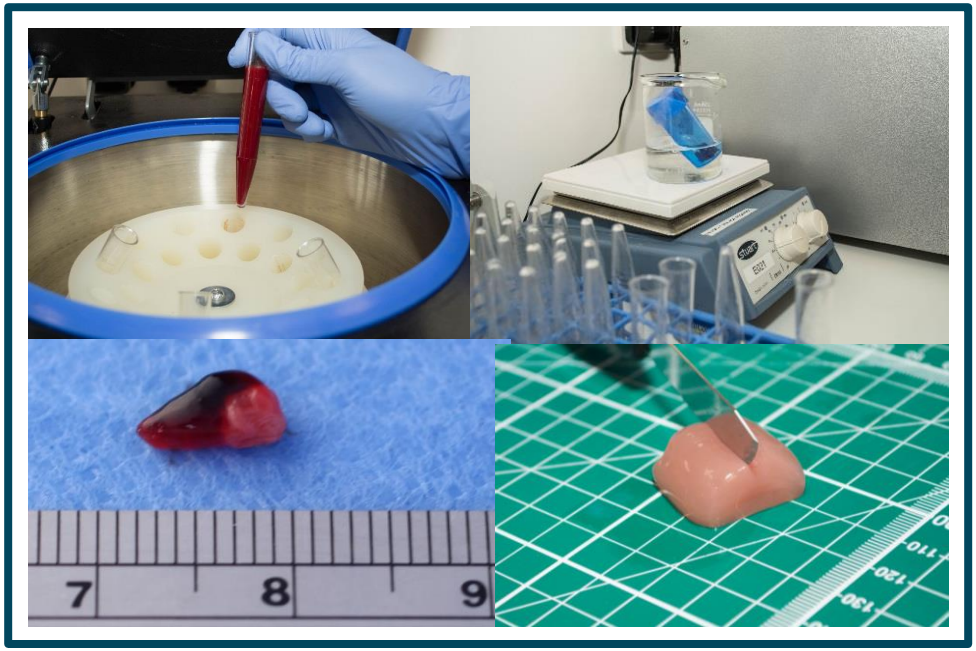


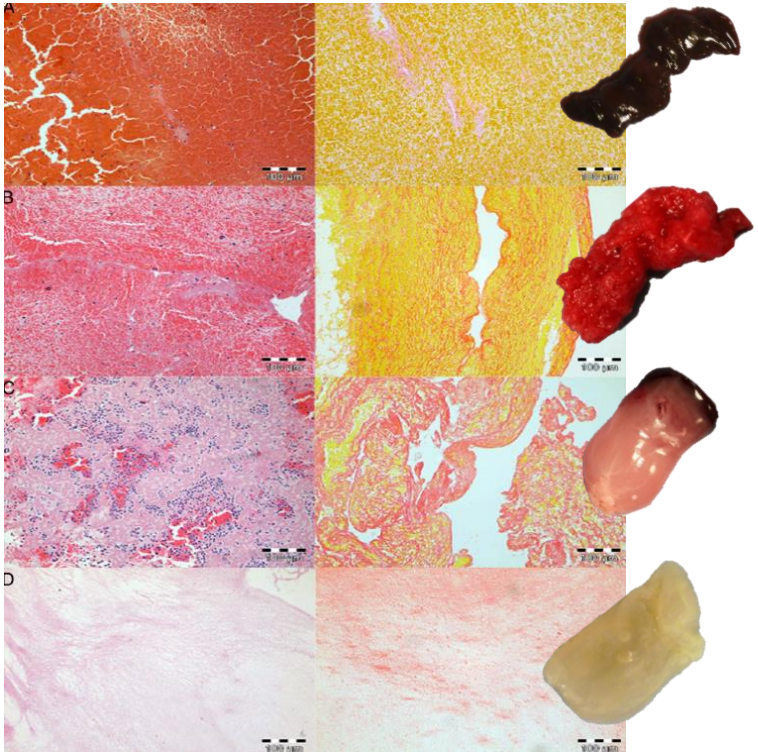


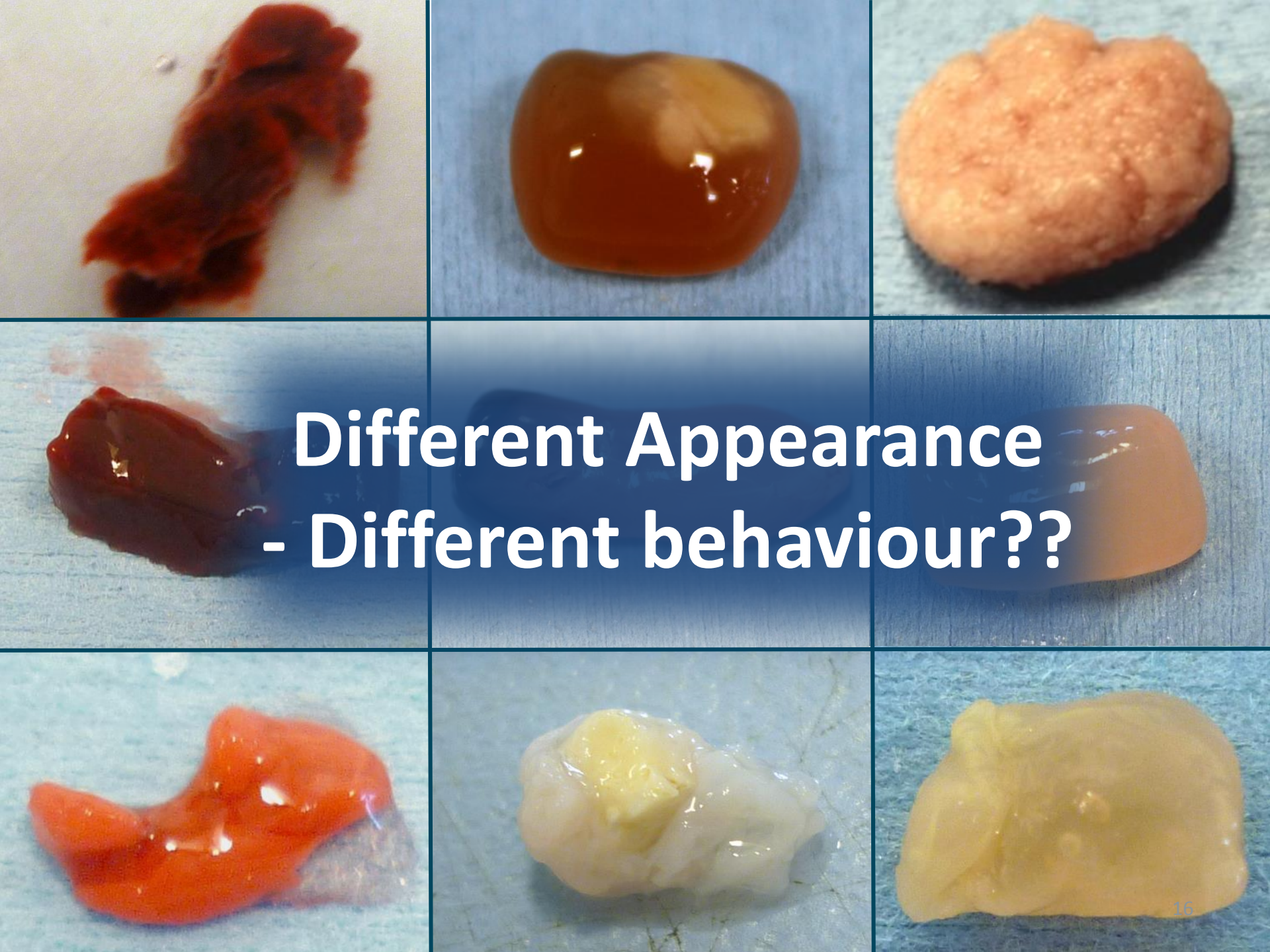
Novel methodology to replicate clot analogs with diverse composition in acute ischemic stroke

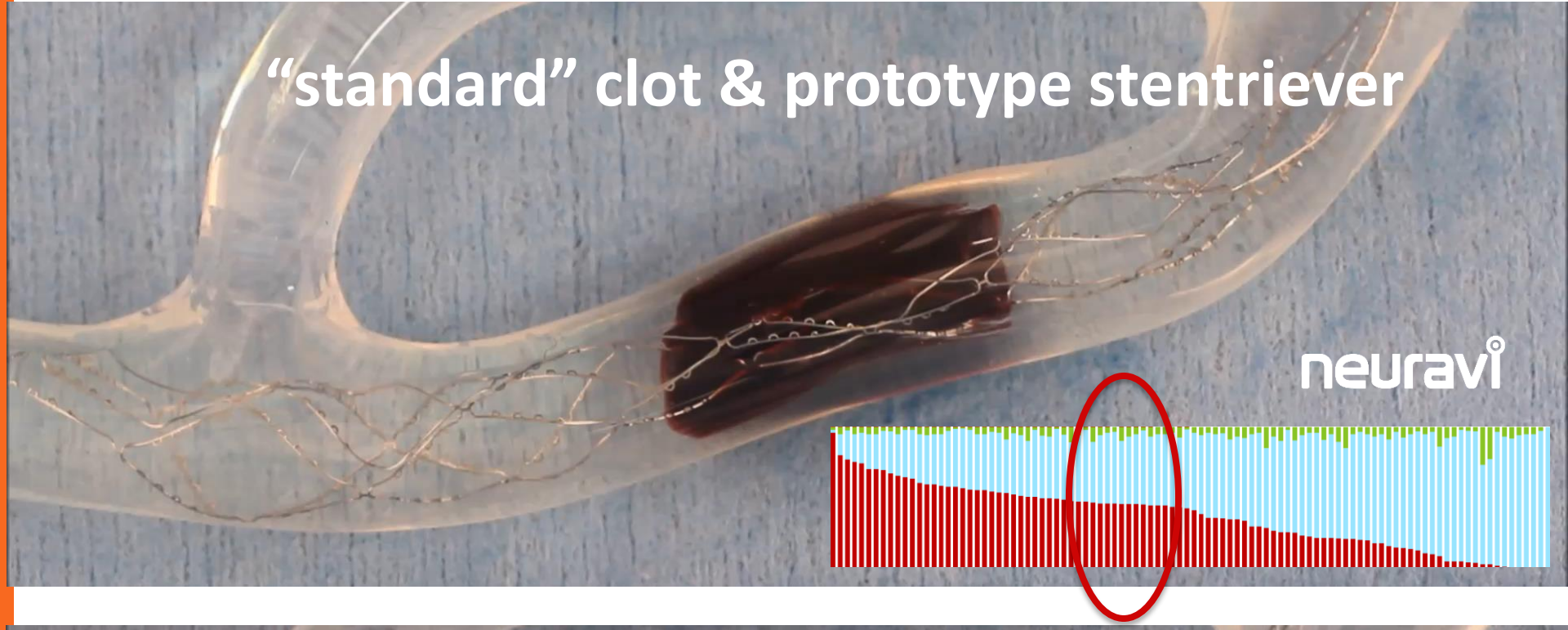
Sharon Duffy[1,2], Michael Farrell[3], Kevin McArdle[2], John Thornton[3], David
Eleanor Rainsford[1], Liam Morris[1], David S Liebeskind[4], Eugene MacCarth
Michael Gilvarry[2]

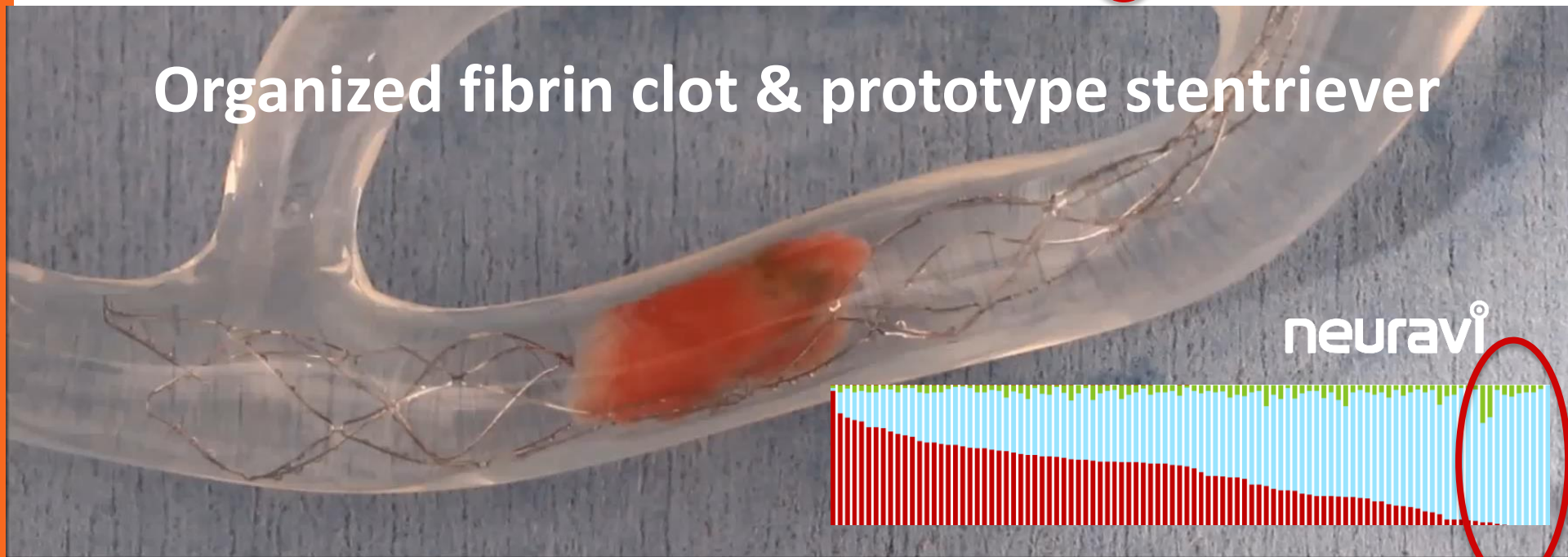
JNIS






Different Appearance
- Different behaviour??

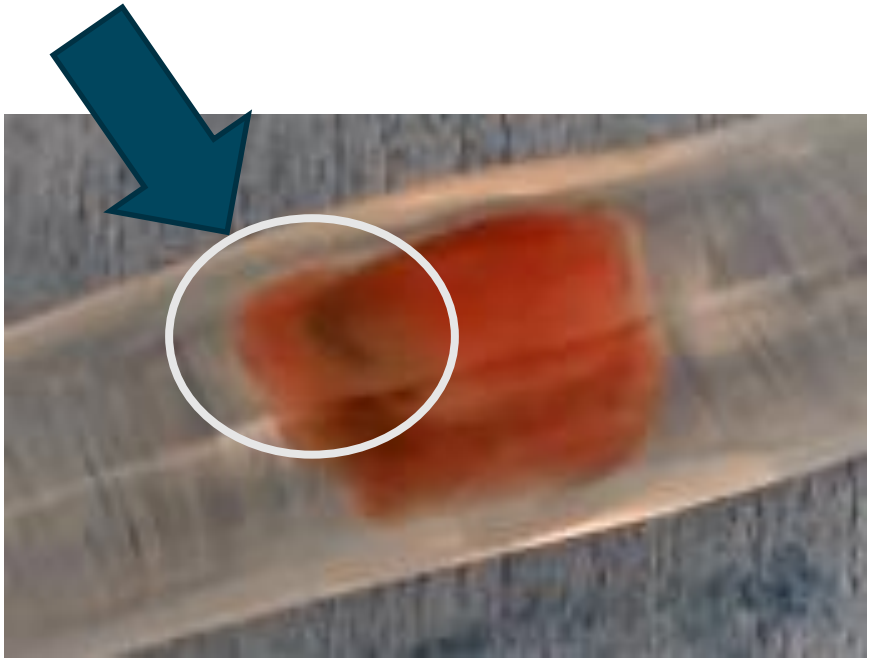

“standard” clot & prototype stentriever
neuravi


Organized fibrin clot & prototype stentriever
neuravi

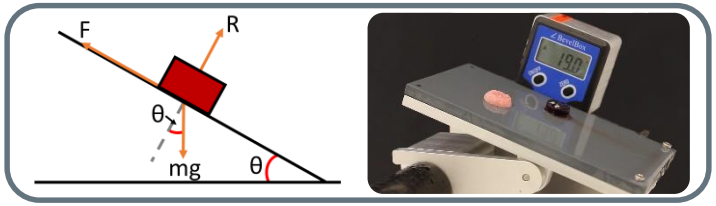
Better or Worse?

Before Pass

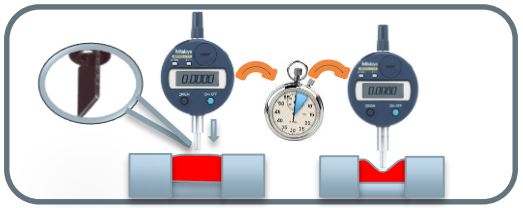
After One Pass



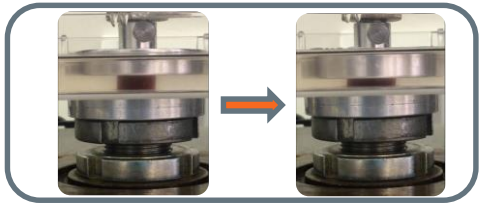
FRICTION



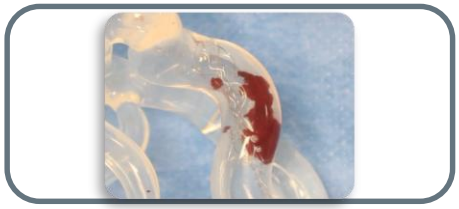
INDENTATION



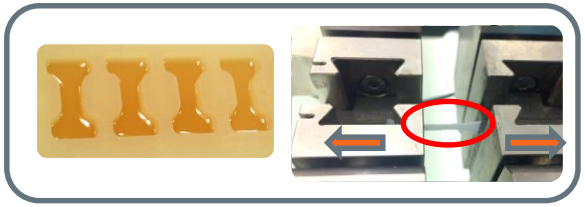
COMPRESSION



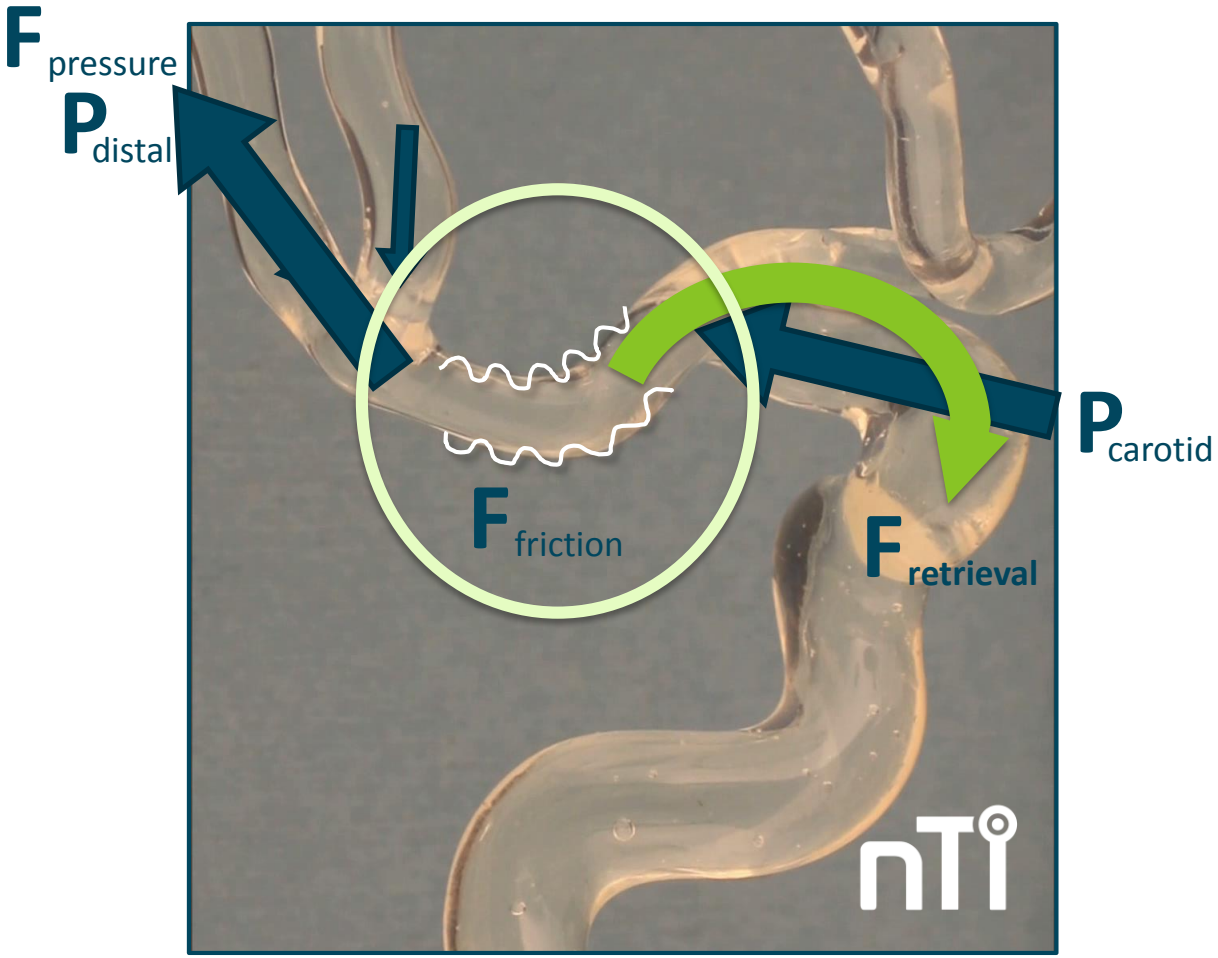
FRAGMENTATION



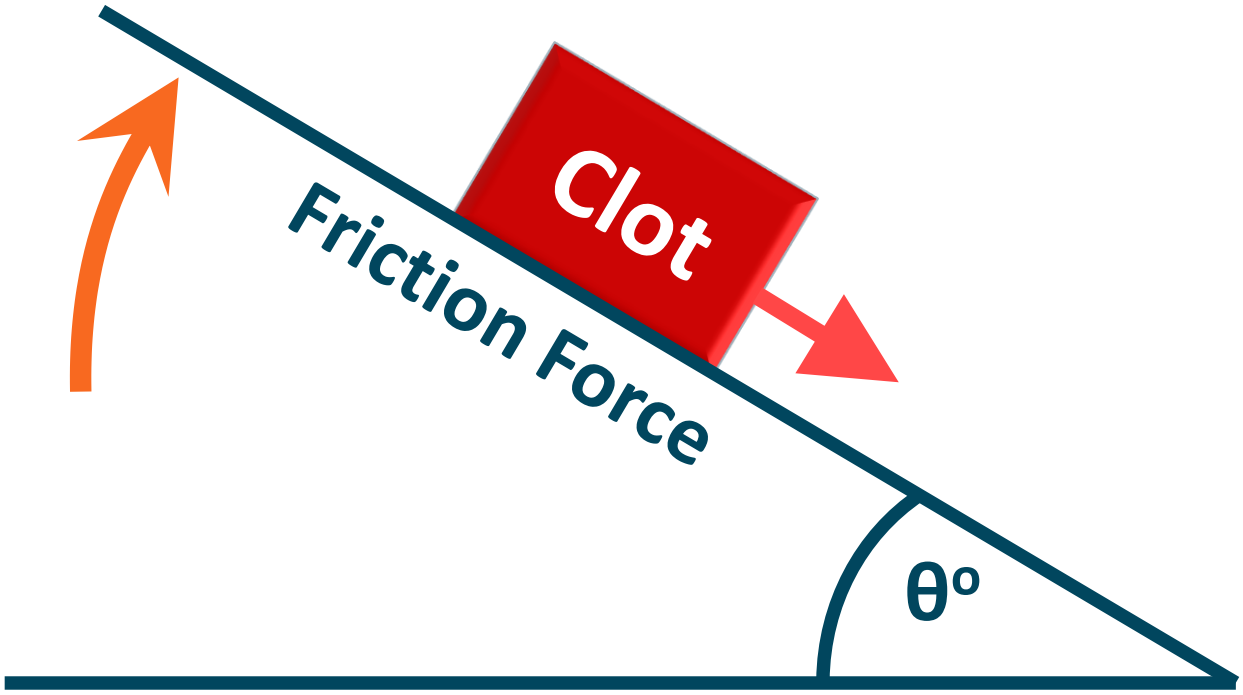
TENSILE



Hydromechanical Forces on Clot

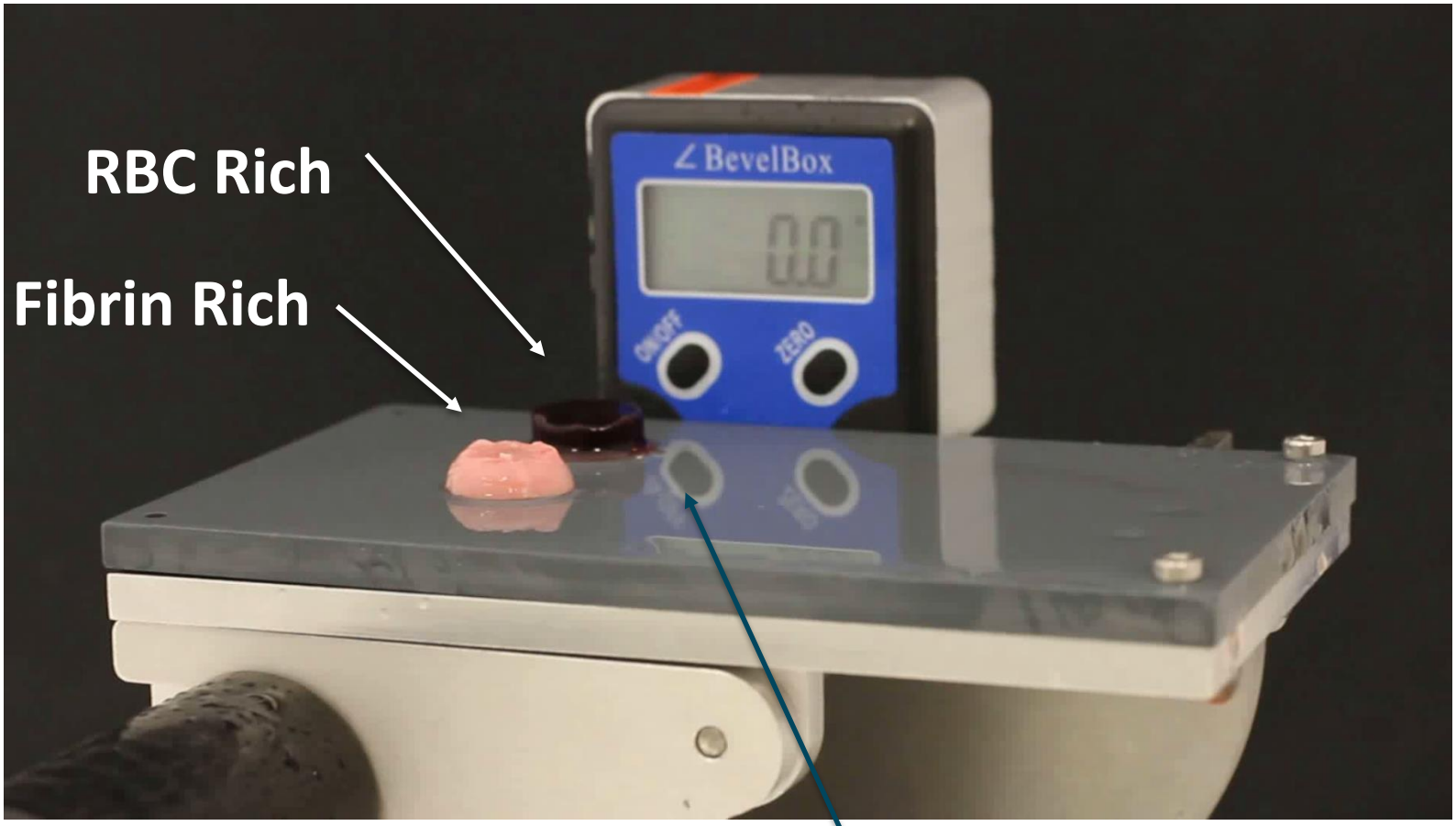


Friction Test Method



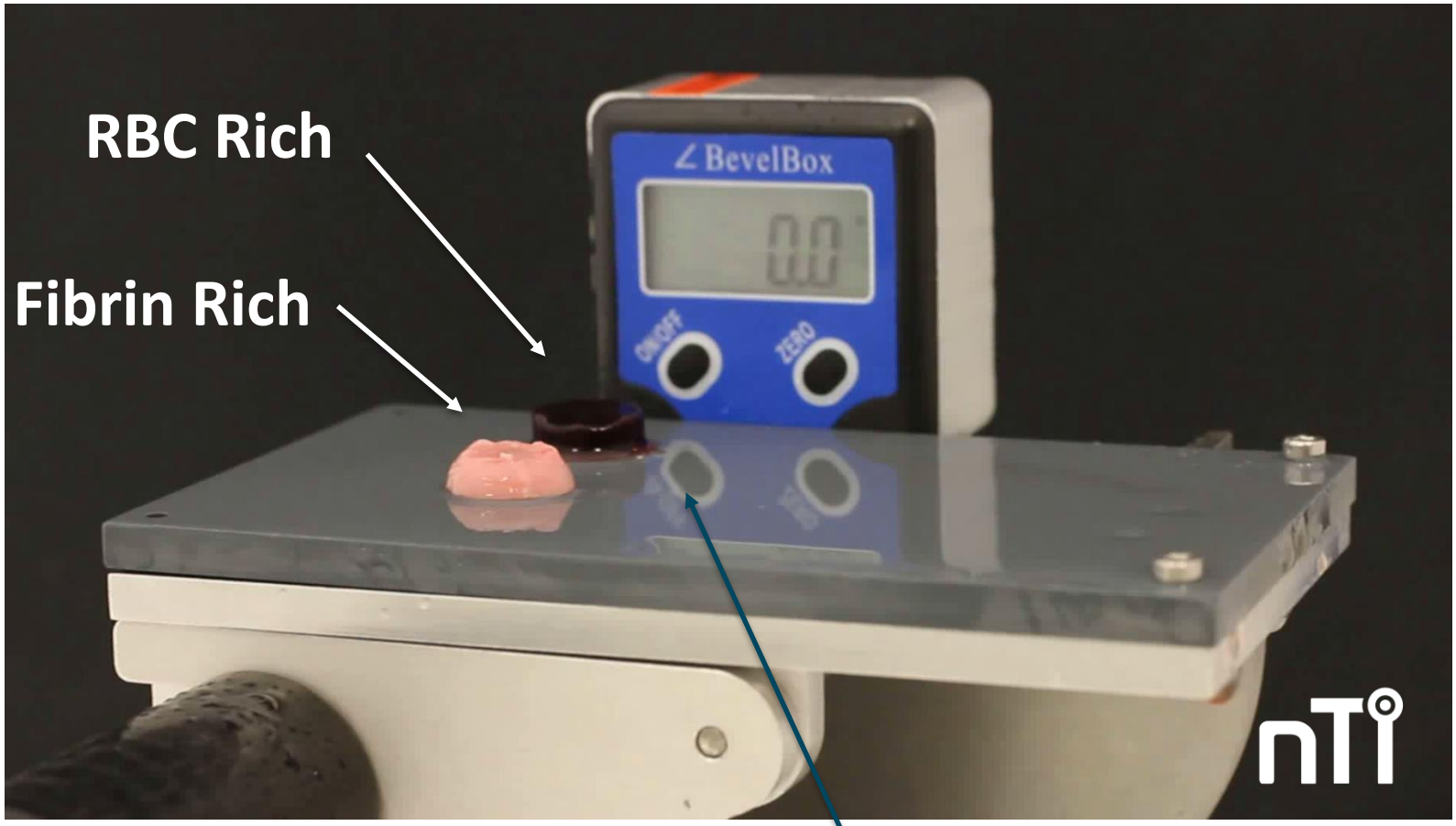
Coefficient of Friction μ = Tanθ

Friction Test Method



Tested on a variety of substrates materials, incl. artery

Friction Test Method



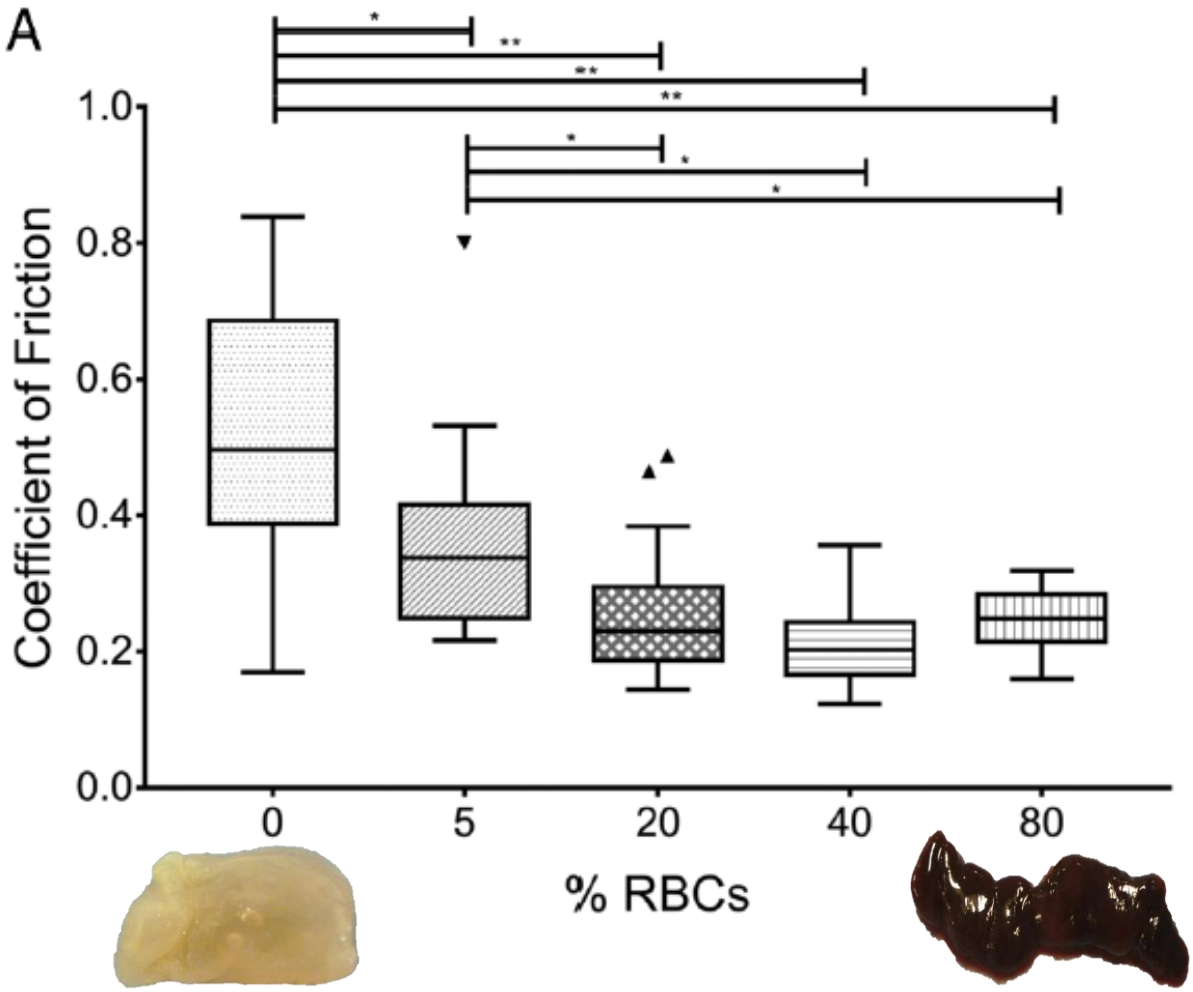
Tested on a variety of substrates materials, incl. artery

ORIGINAL RESEARCH

JNIS

Clot friction variation with fibrin content; implications for resistance to thrombectomy

Gillian M Gunning,[1] Kevin McArdle,[1] Mahmood Mirza,[1] Sharon Duffy,[1,2] Michael Gilvarry,[1] Patrick A Brouwer[3]



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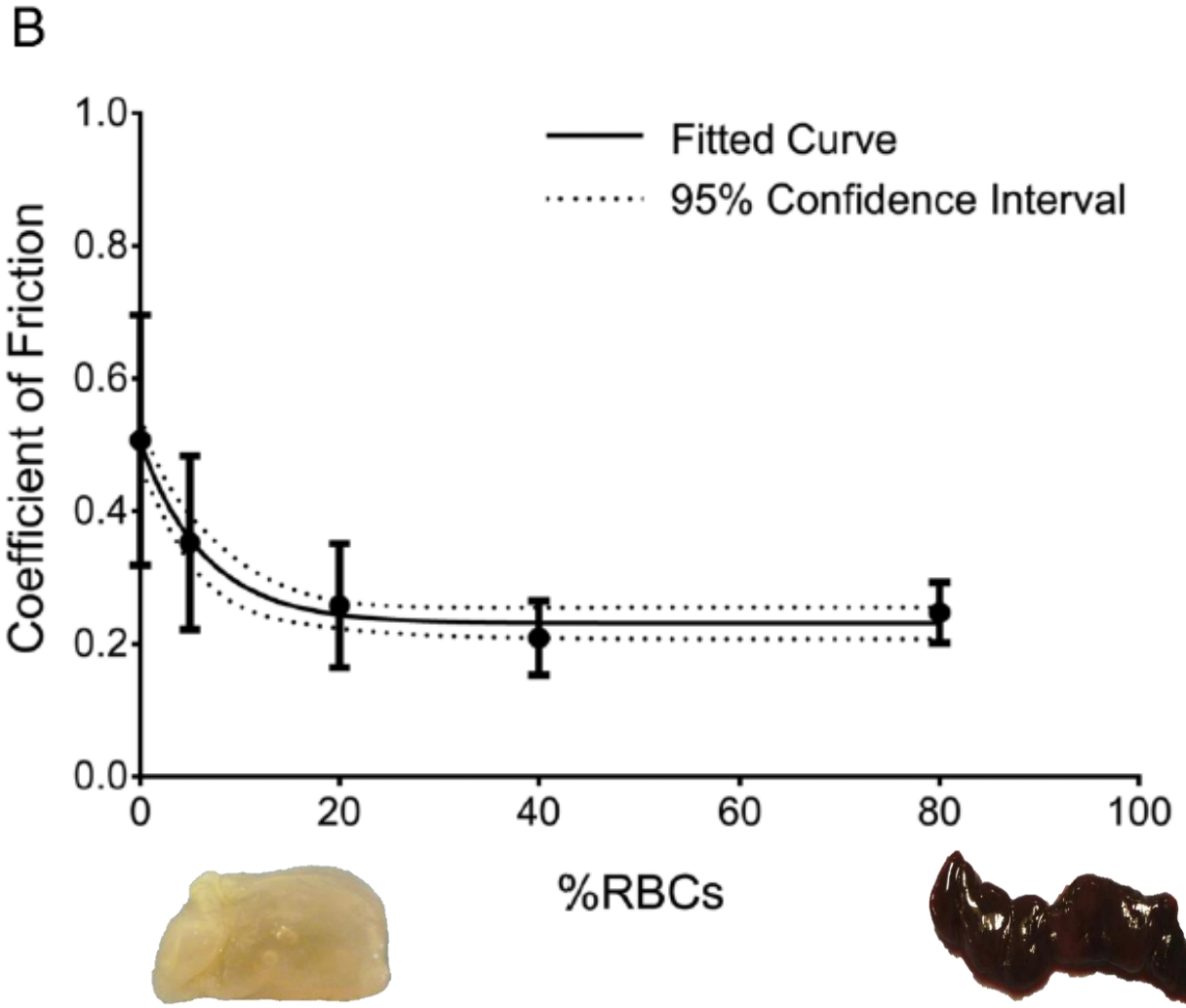
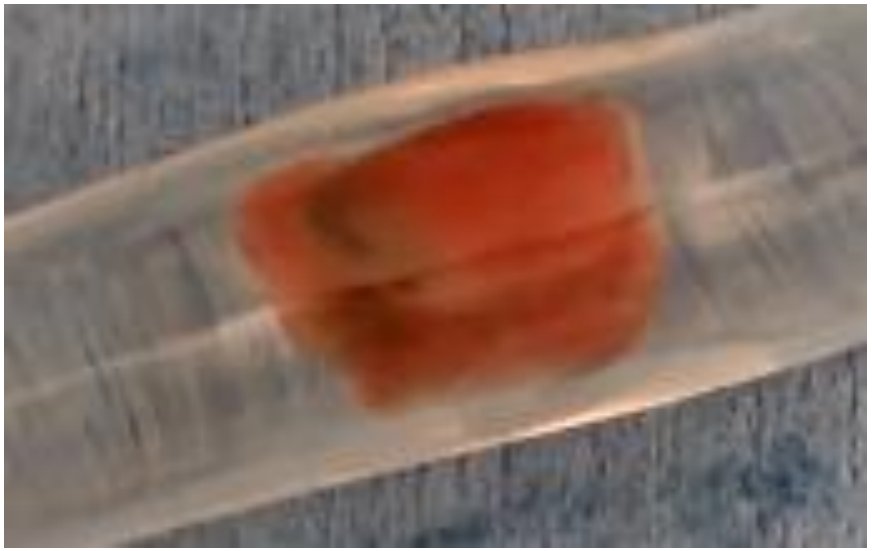


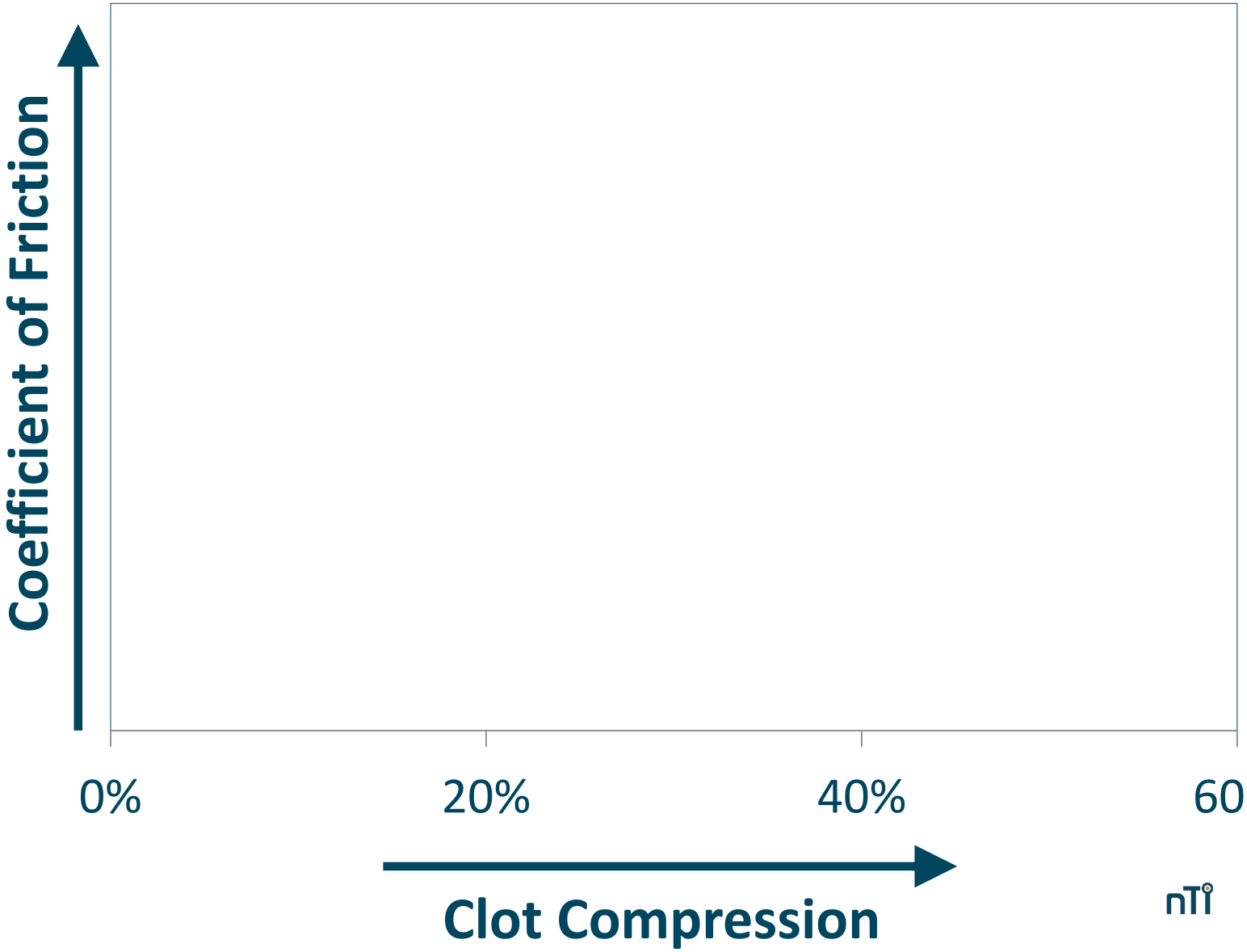
Simulate Effects of Single Pass

Before Pass

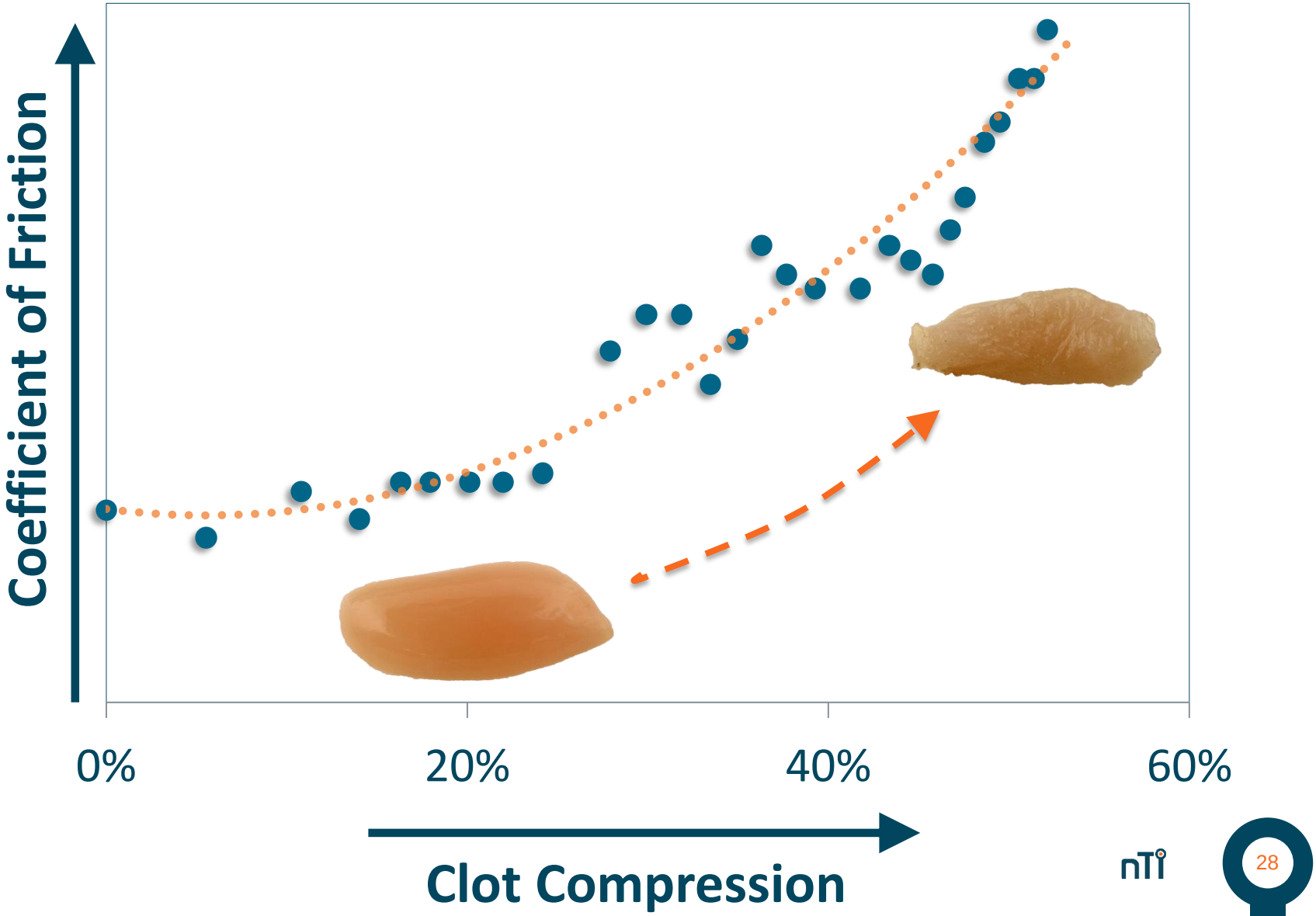
After One Pass



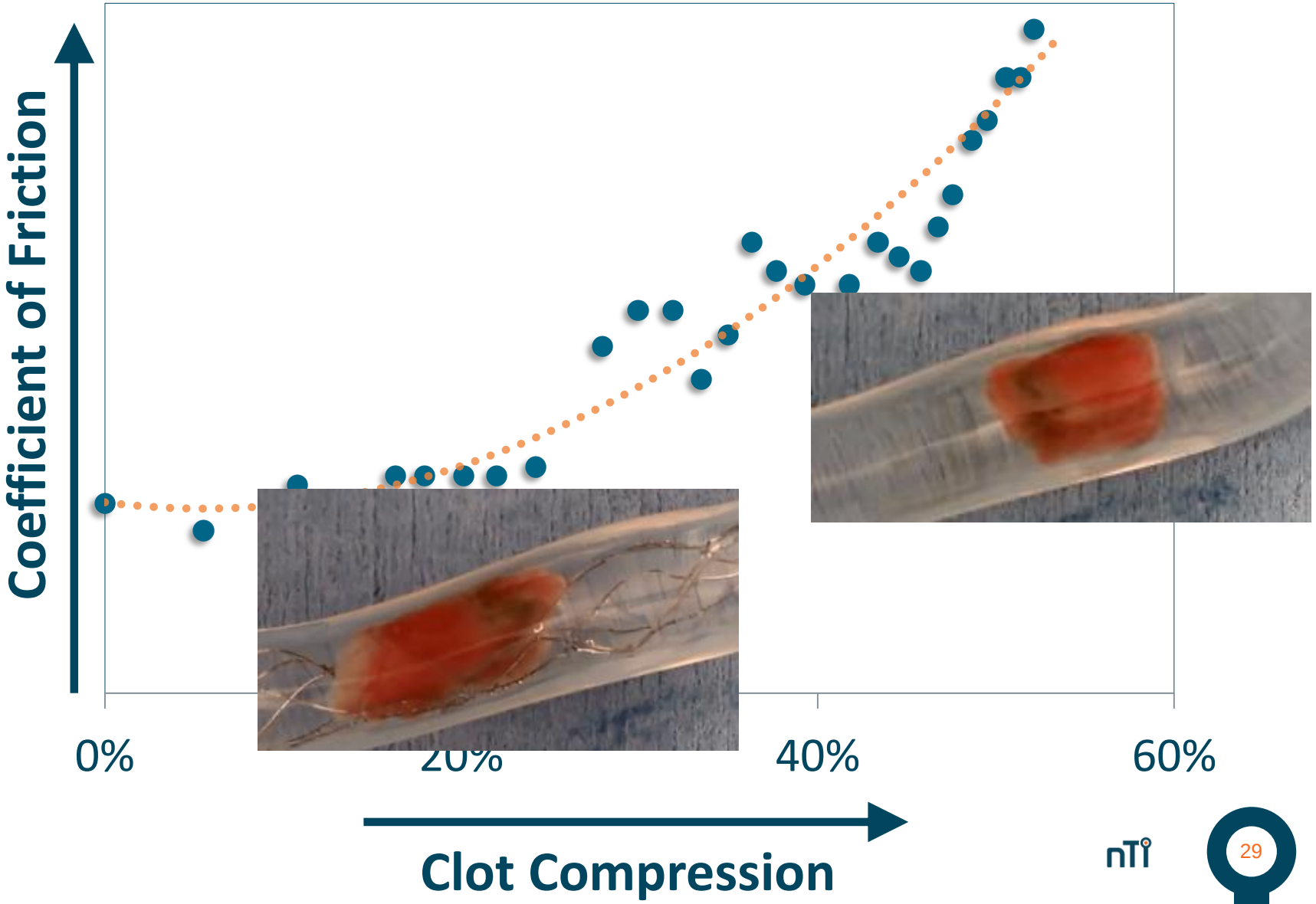
Clot Compression increases Friction



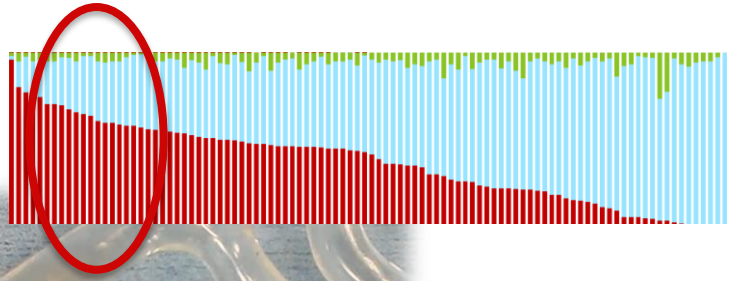
Clot Compression increases Friction

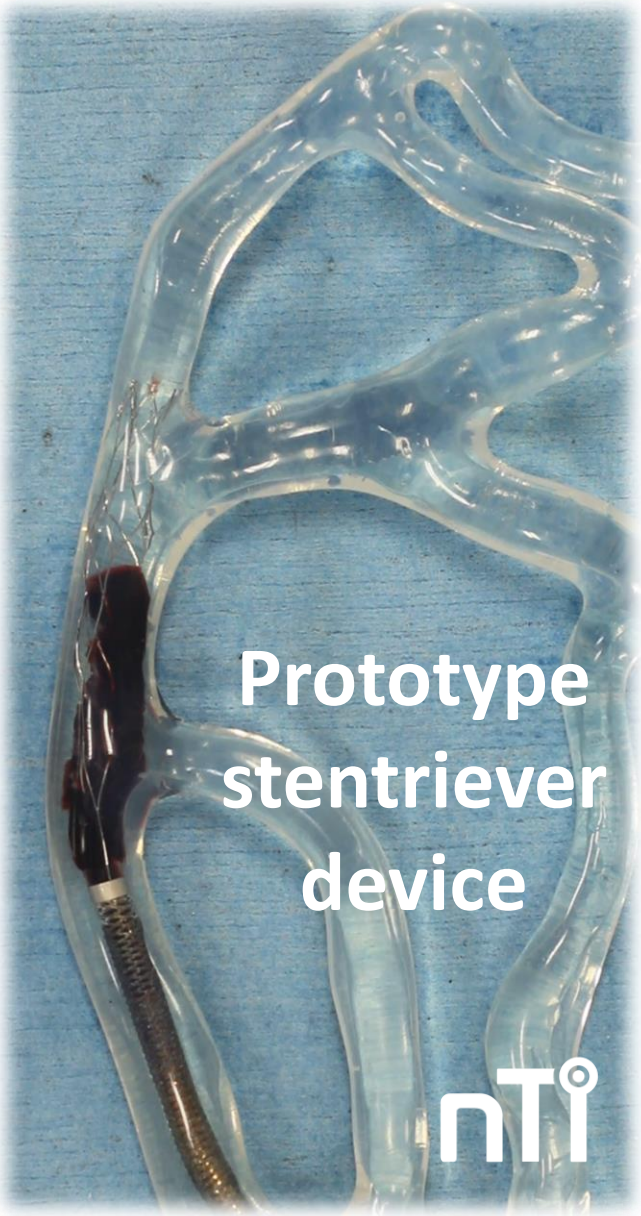


Better or Worse?



Friable RBC rich clot:





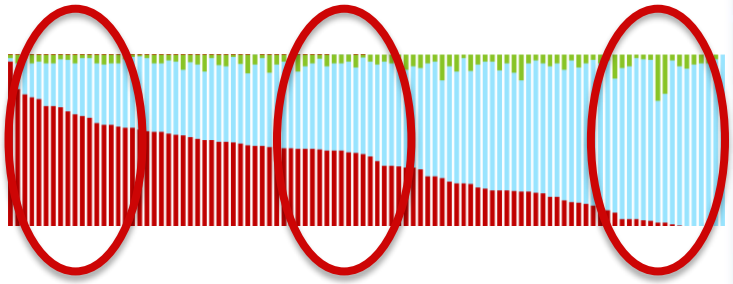
Heterogenous Clot Analogues

Image courtesy of Dr P. Brouwer, Karolinska University Hospital.

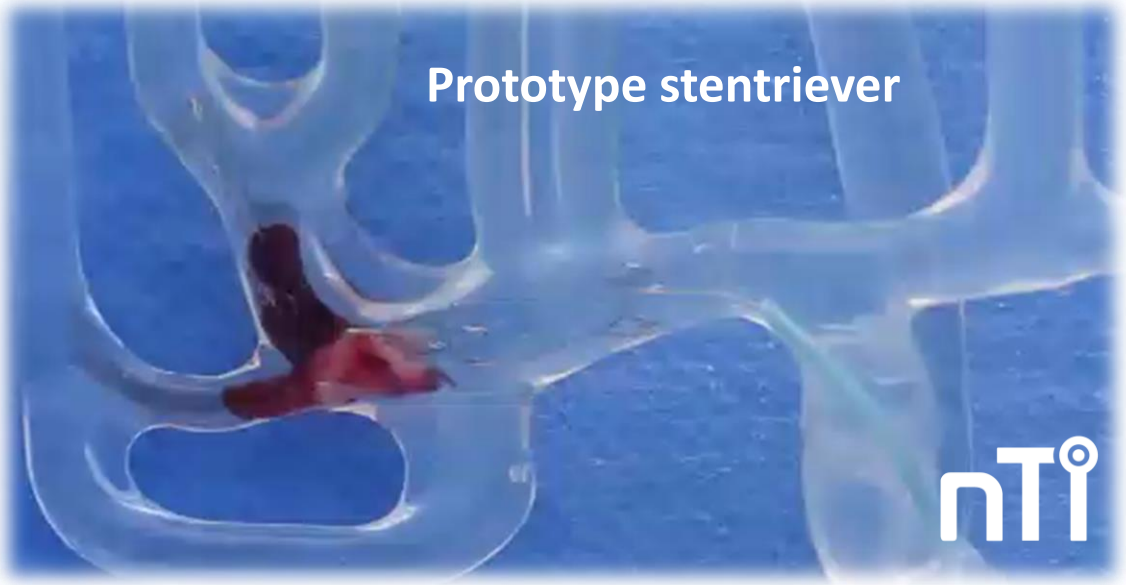
CLOT ANALOGS

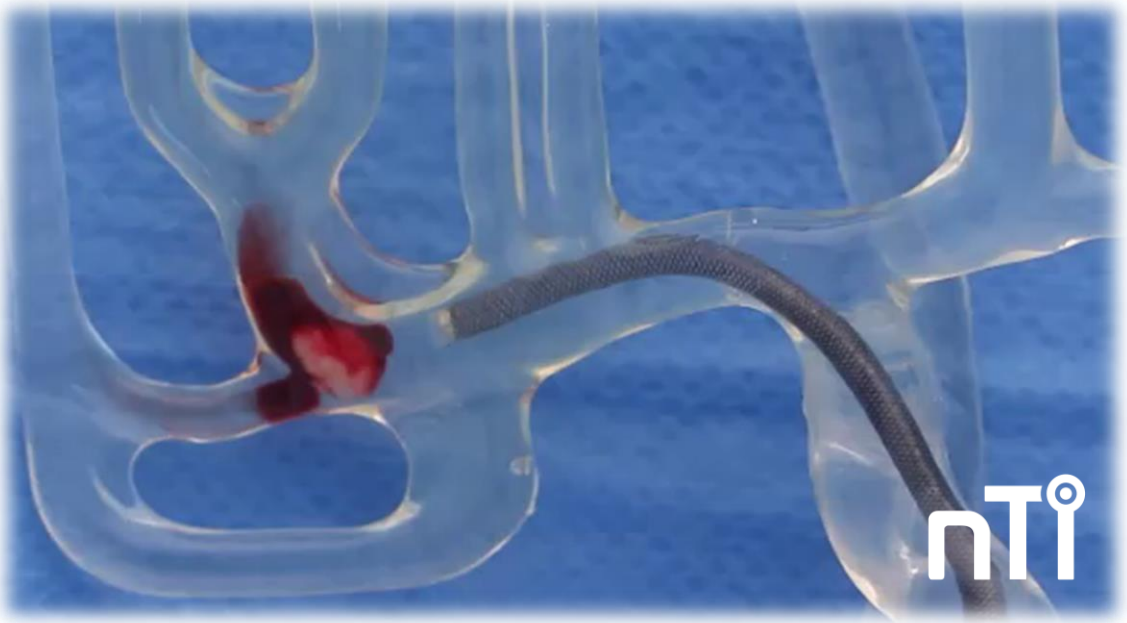
Image courtesy of Dr M. Stauder , Alfried Krupp Krankenhaus, Essen

Heterogenous clots



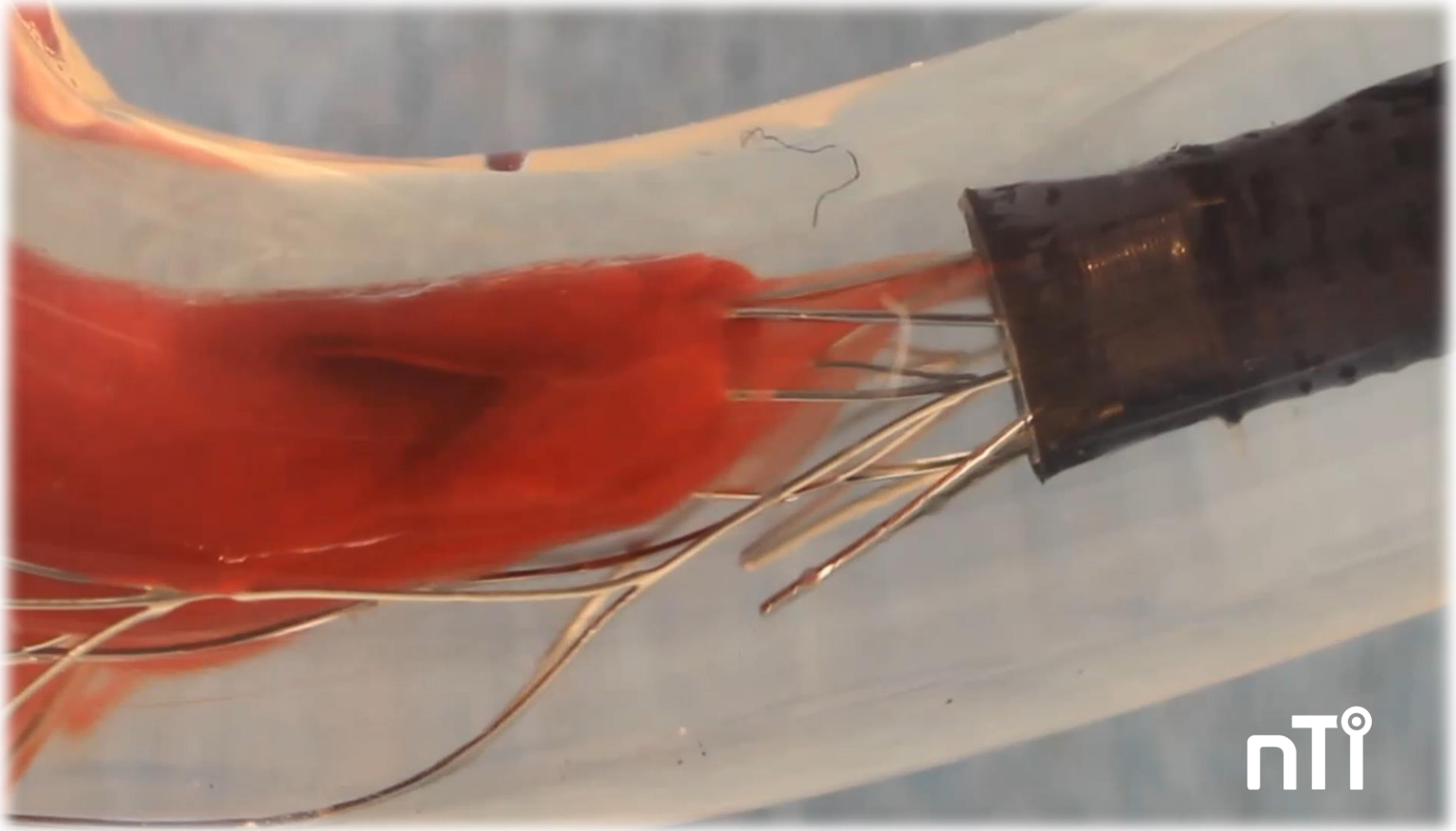
- Failed retrievals most interesting!
- Many different mechanisms possible
- May not be apparent on Angiogram





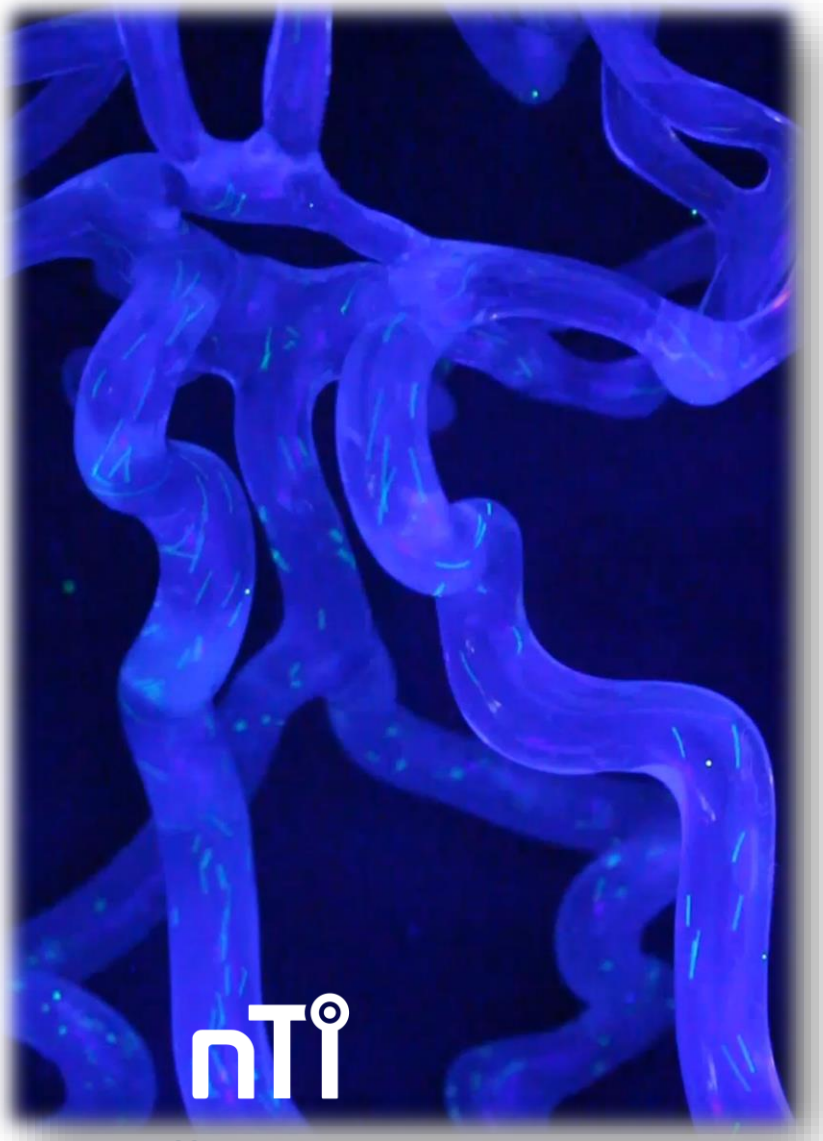
Impact of Procedural Technique variants

Interaction with Devices



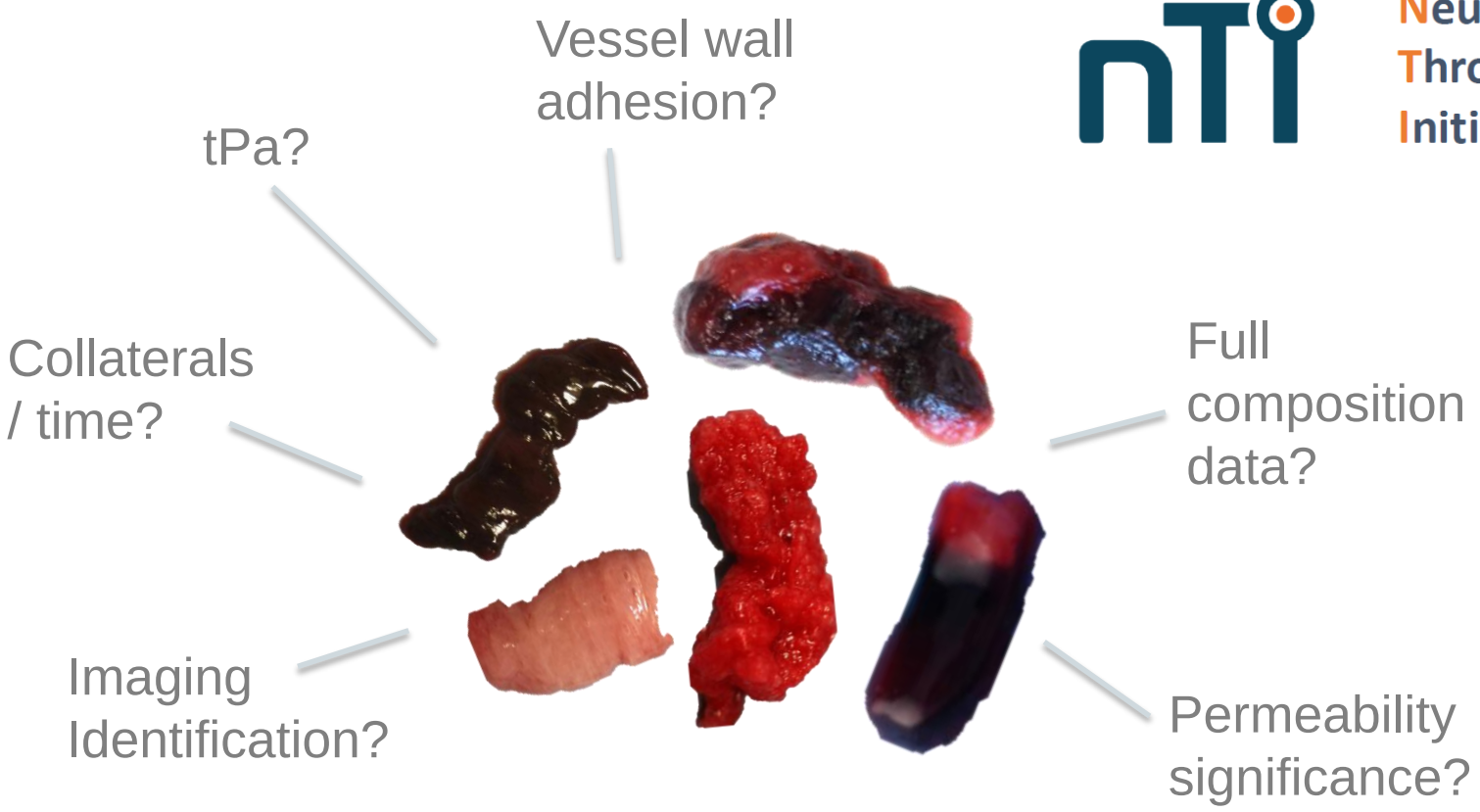
Retrieval Techniques

Retrieval Techniques + Flow Visualization



Conclusion

Neuravi Thromboembolic Initiative



- **Different clot types present different challenges.**
- **Greater understanding can lead to better solutions.**
- **In-vitro modelling can be a valuable tool, but output is only as good as the input, and clot is a key input.**
- **A lot left to learn!**

Team

Neuravi
Thromboembolic
Initiative

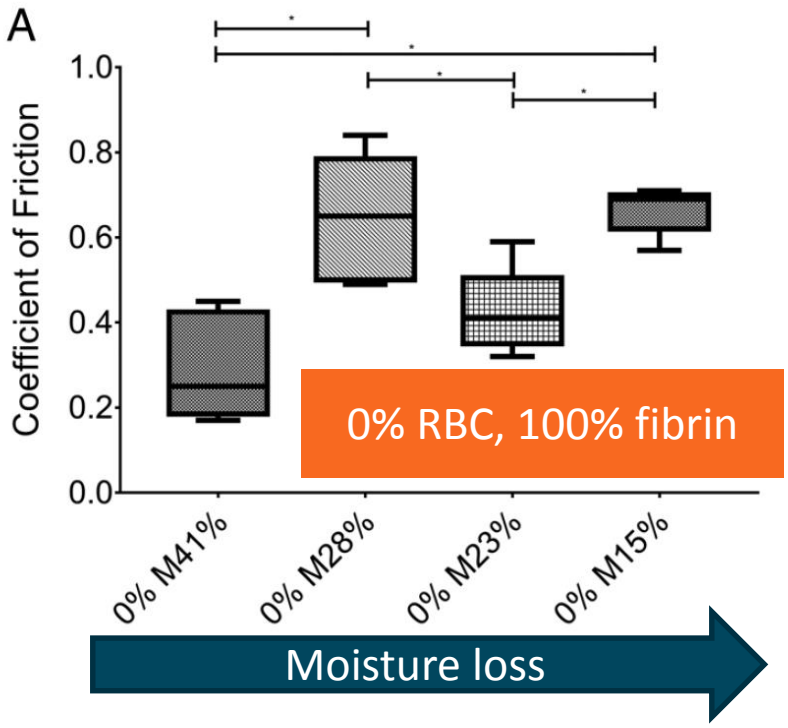
- Michael Gilvarry, VP R&D
- Mahmood Mirza, BASc, MD
- Gillian Gunning, PhD
- Sharon Duffy, PhD in training
- Maeve Holian, MSc
- Brian Fahy, B.Eng.
- Sean O'Rourke, Intern

Thank you!

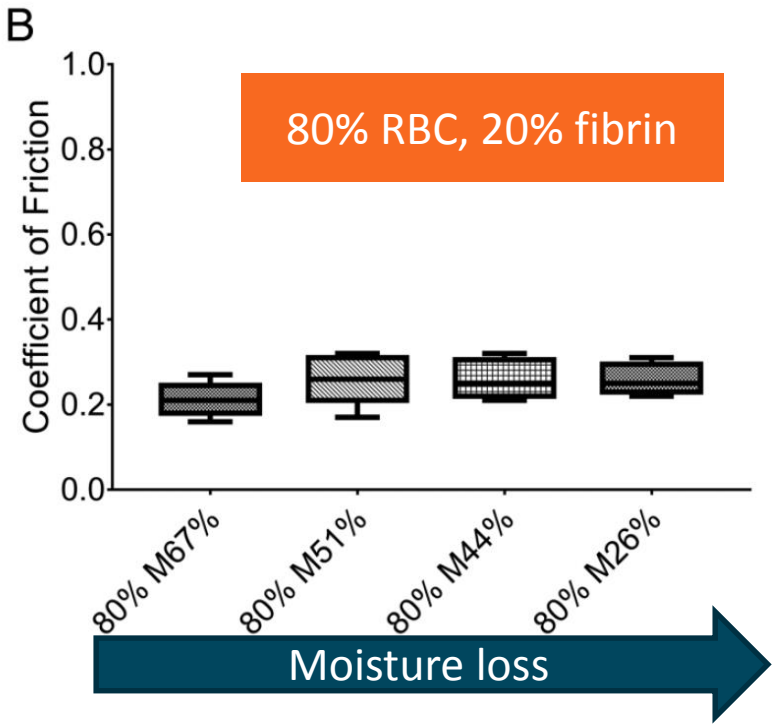
Backup

Moisture loss

- May impact variability
- No trend



- No significant impact



ORIGINAL RESEARCH

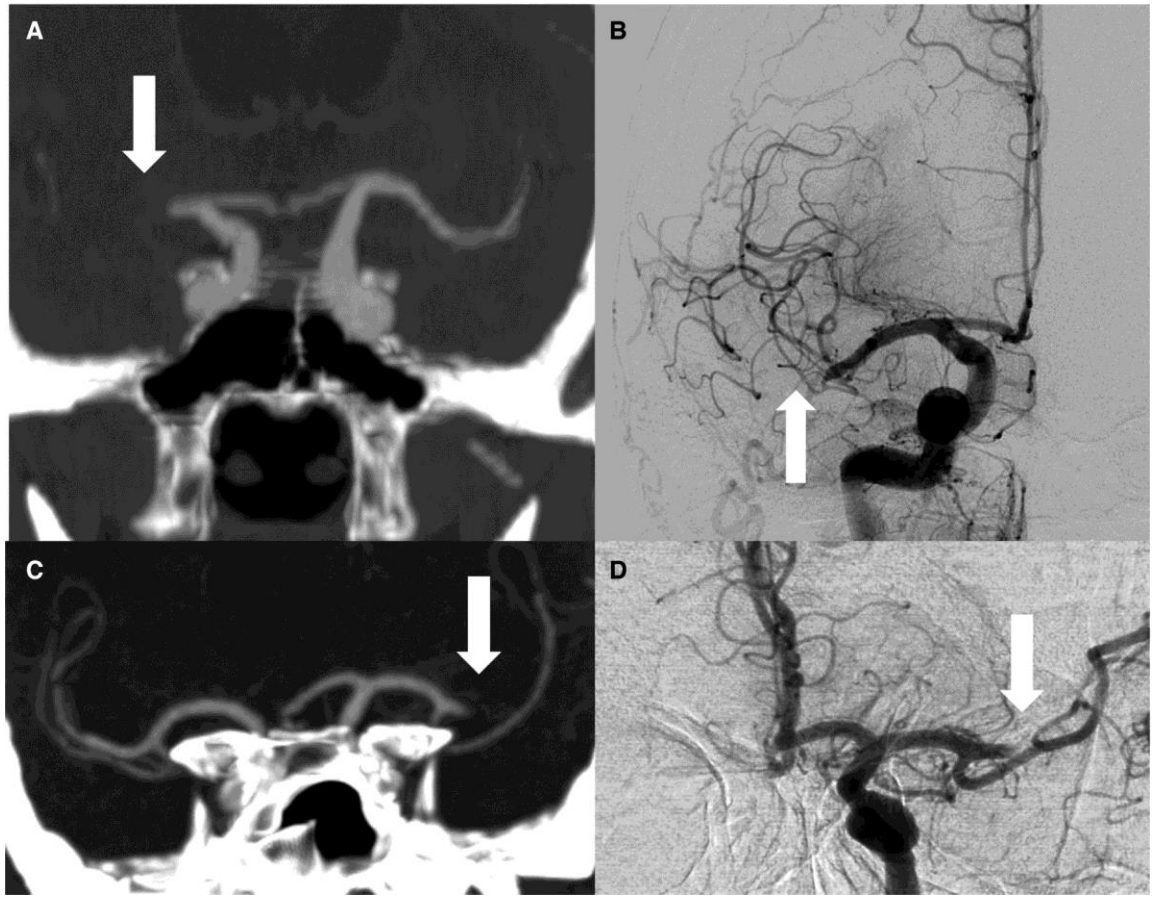
Correlation of imaging and histopathology of thrombi in acute ischemic stroke with etiology and outcome: a systematic review

Waleed Brinjikji,[1] Sharon Duffy,[2] Anthony Burrows,[1] Werner Hacke,[3] David Liebeskind,[4] Charles B L M Majoie,[5] Diederik W J Dippel,[6] Adnan H Siddiqui,[7] Pooja Khatri,[8] Blaise Baxter,[9] Raul Nogeuira,[10] Matt Gounis,[11] Tudor Jovin,[12] David F Kallmes[1]

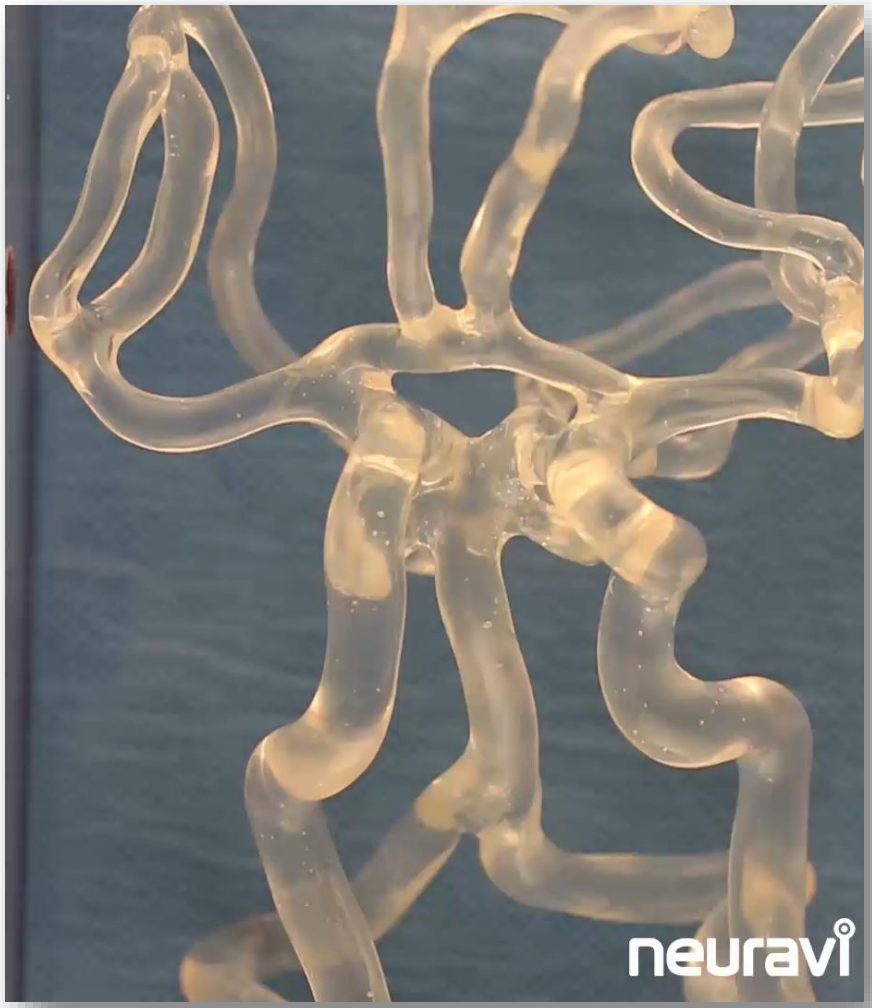
Question	Articles	Cor?	Comments
Histology and etiology	9	No	Conflicting RBC – A-fib, large-artery
Histology and angio outcomes	4	No	
Imaging and histology	8	Yes	HAS -> RBC SVS -> RBC
Imaging and angio outcomes	8	Yes/No	HAS -> better outcomes - 5 positive, 1 no, 1 negative SVS -> better oucomes - 2 positive
Imaging and etiology	7	No	Conflicting. Meta-analysis said no.

Thrombus Migration in the Middle Cerebral Artery: Incidence, Imaging Signs, and Impact on Success of Endovascular Thrombectomy

Johannes Kaesmacher, MD; Christian Maegerlein, MD; Mirjam Kaesmacher; Claus Zimmer MD; Holger Poppert, MD; Benjamin Friedrich, MD; Tobias Boeckh-Behrens, MD; Justus F. Kleine, MD



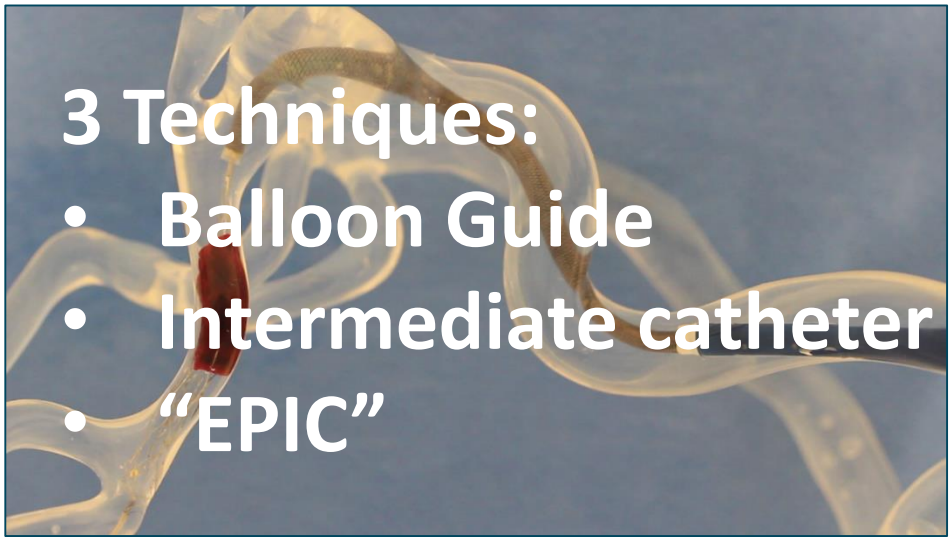
Thrombus Migration *in vitro*



BG vs IC

2 x Clot Types Tested	
Fresh RBC-Rich n = 30	Firm fibrin n = 30

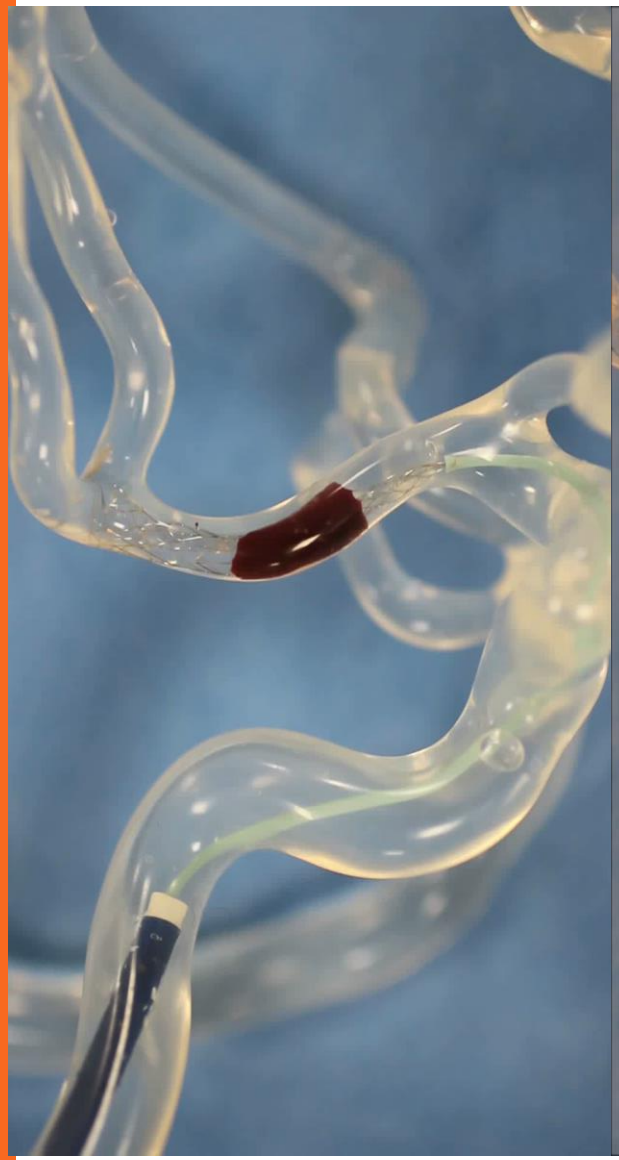
4 x Intermediate Catheters	CSA
Sofia 0.055”	1.5 mm^2
Navien 0.058”	1.7 mm^2
5 Max Ace 0.060”	1.8 mm^2
Navien 0.072”	2.6 mm^2

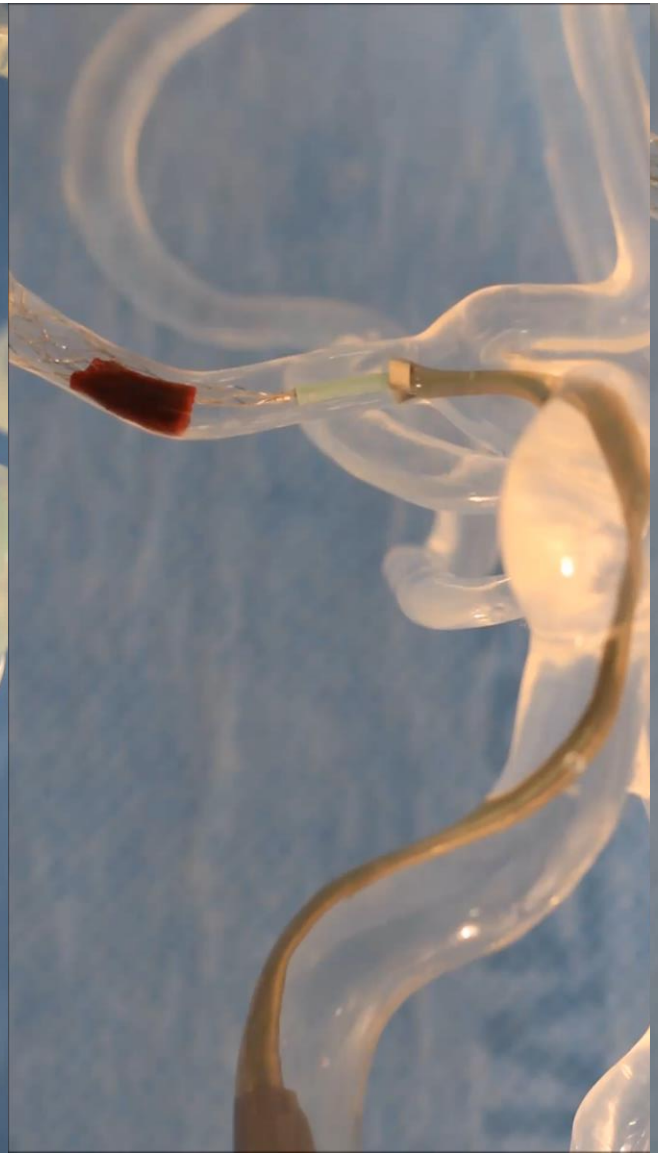


BGC

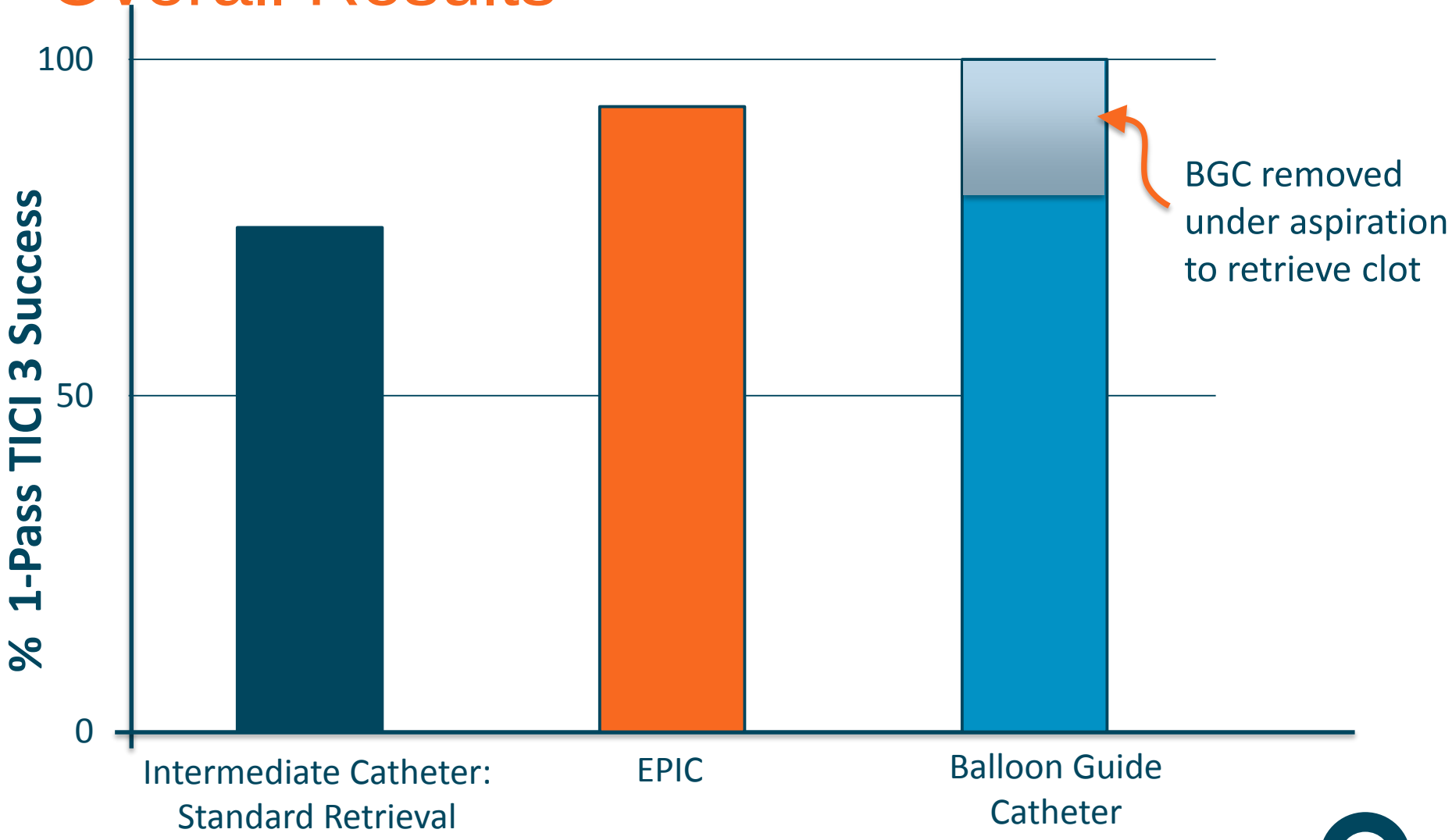
IC Full Retrieval

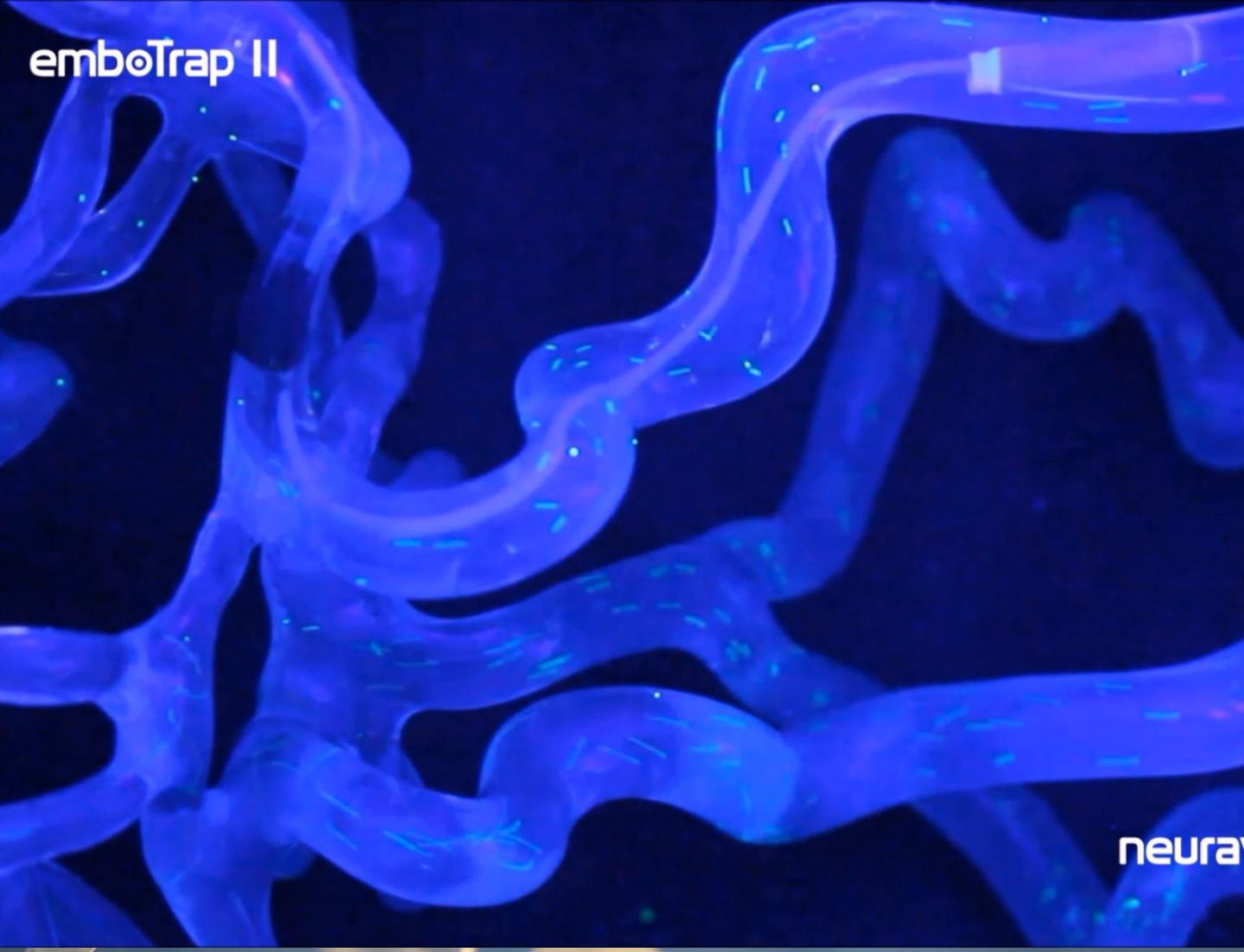
IC EPIC





Overall Results




emboTrap II
neura