3D virtual histology of thrombi through non-contrast-enhanced X-ray propagation-based microCT

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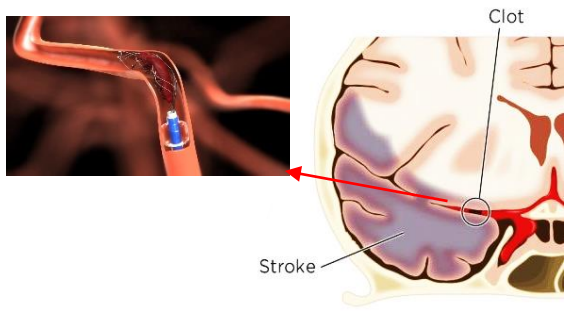
Motivation & Background

- Annually, 15 million people worldwide suffer a stroke, of which 5 million are left permanently disabled [1].
- A treatment choice for **acute ischemic stroke (AIS)** is

Mechanical Thrombectomy (MTB)

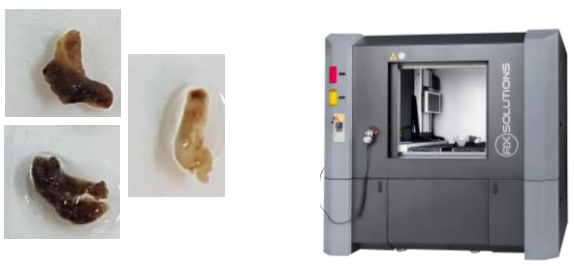


Characterization of thrombi composition can explain mechanical properties of clot and improve the outcome of MTB.

- The standard method for composition analysis is optical microscopy **BUT**:
  - Only for 2D characterization
  - Limited to small field of view
  - Needs staining (invasive)

Methodology

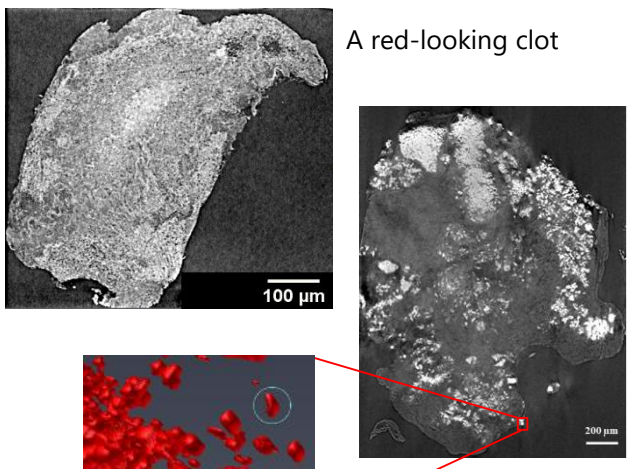
- **X-ray propagation-based phase contrast microtomography** :
  - 3D characterization
  - Full field of view
  - No contrast agent (non-invasive)
  - High resolution & phase contrast
- **Different dried blood clot samples were analyzed through micro/nanoCT**



- **Correlation of microCT data with :**
  - Scanning electron microscopy (SEM)
  - X-ray diffraction (XRD)
  - Electron dispersive spectroscopy (EDS)

Results

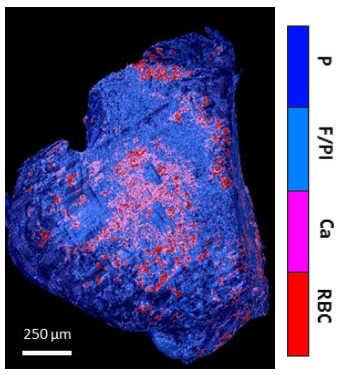
MicroCT reconstructed slices of two patient clots [2]:



A red-looking clot

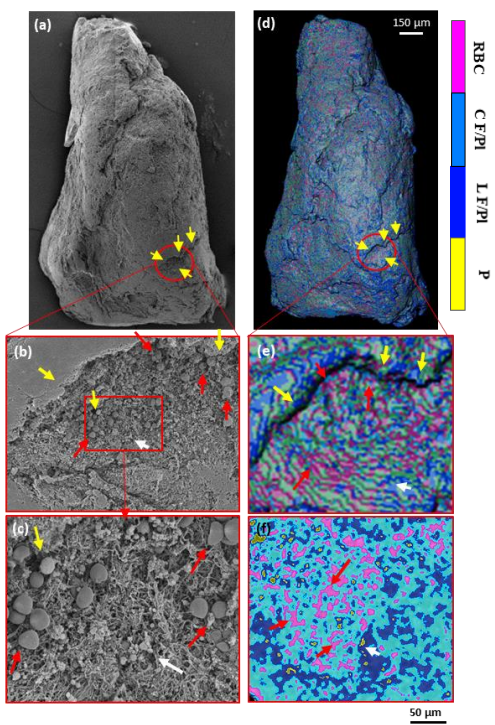
A white-looking clot, inset: 3D rendering of red blood cells (RBCs)

MicroCT 3D rendering of a segmented white blood clot volume. The volume fraction of each Structure can be Calculated [2].



P: porosity
F/Pl: fibrin/platelets
Ca: Calcifications
RBC: red blood cells

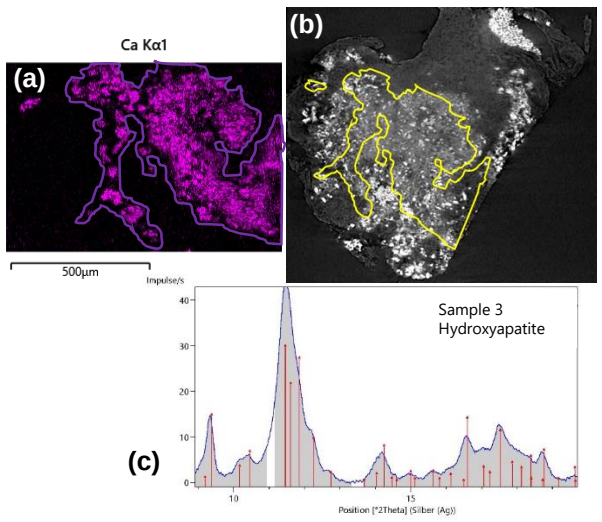
Co-registration of microCT structural information with SEM images [2].



(a) SEM image of a red clot surface, (b, c) zoomed ROIs from (a); (d) 3D rendering of reconstructed microCT volume; (e, f) zoomed ROIs from (d). Red, yellow, and white arrows points to RBCs, structural landmarks, and porosity, respectively. C F/Pl and L F/PL are compact and loose F/Pl regions.

Analysis

- Aggregates or individual RBCs are distinguished as hyper-intense signal.
- Fibrin-platelet masses are detected as low to intermediate signals, depending on the compactness.
- Calcifications appear as glassy opacity.
- XRD (phase) and EDS (elemental) analysis confirm the nano-polycrystaline calcifications in microCT, detected as ground-glass opacity [2]:



(a) EDS measurement for Ca, (b) corresponding reconstructed microCT slice, co-registered with the EDS map, (c) XRD measurement.

Conclusion & Outlook

- It was demonstrated that X-ray phase-contrast microCT can provide fibrillary and cellular structures of the whole clot volume without any contrast agent.
- RBC shape and sizes are consistent with high resolution SEM images.
- MicroCT can provide volume fraction of porosity and clot structures, important in the mechanical properties of a clot.
- In a large-scale study combined with radiomics analysis, the microCT data can be correlated with clinical CT data to characterize thrombi and help to choose the best MTB strategy for thrombus management.

Acknowledgement

FNSNF
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References

1- P. B. Sporns, *et al.* Histological Clot Composition is Associated with Preinterventional Clot Migration in Acute Stroke Patients. *Stroke* 50, 2065–2071 (2019).
2- S. Saghamanesh, D.D. LaGrange, P. Reymond, I. Wanke, K-O. Loevblad, A. Neels, R. Zboray. Non-contrast-enhanced volumetric assessment of blood clot histology through high-resolution propagation-based X-ray microtomography, under review in *Scientific Reports*.

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