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Ultra-sensitive Microvessel Imaging for Breast Tumors: Initial Experiences

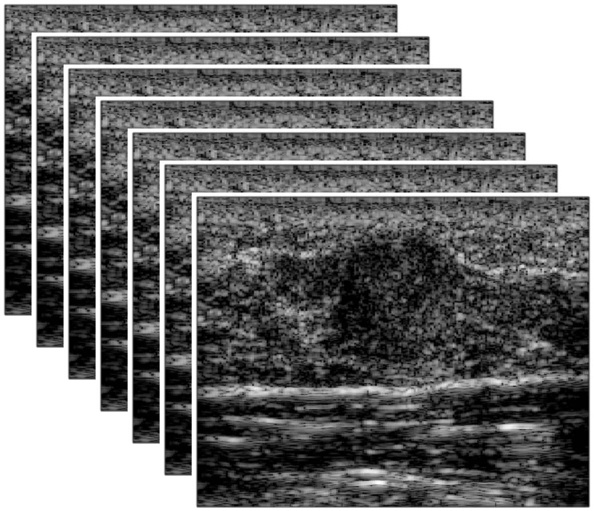
Ping Gong[1], Chengwu Huang[1], Pengfei Song[1], Wenwu Ling[2], Robert T. Fazzio[1], Kathryn J. Ruddy[3], Karthik Ghosh[4], Duane D. Meixner[1], and Shigao Chen[1]

1. Department of Radiology, Mayo Clinic College of Medicine and Science, Rochester, MN, United States
2. Department of Ultrasound, West China Hospital of Sichuan University, Sichuan, China
3. Department of Oncology, Mayo Clinic, Rochester, MN, United States
4. Department of General Internal Medicine, Mayo Clinic College of Medicine and Science, Rochester, MN, United States

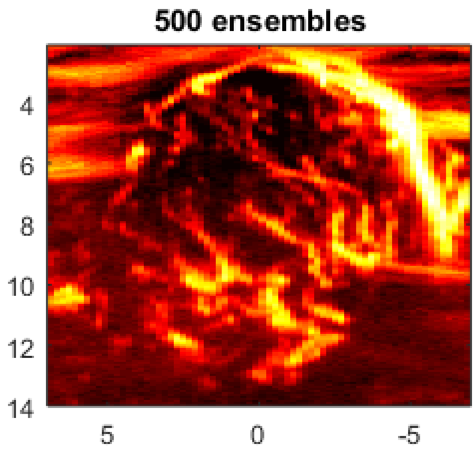
Principle of Ultra-sensitive Microvessel Imaging

High frame rate = High ensemble count = High Doppler sensitivity

Ultrafast plane wave imaging frames
(500-4000 ensembles/second)

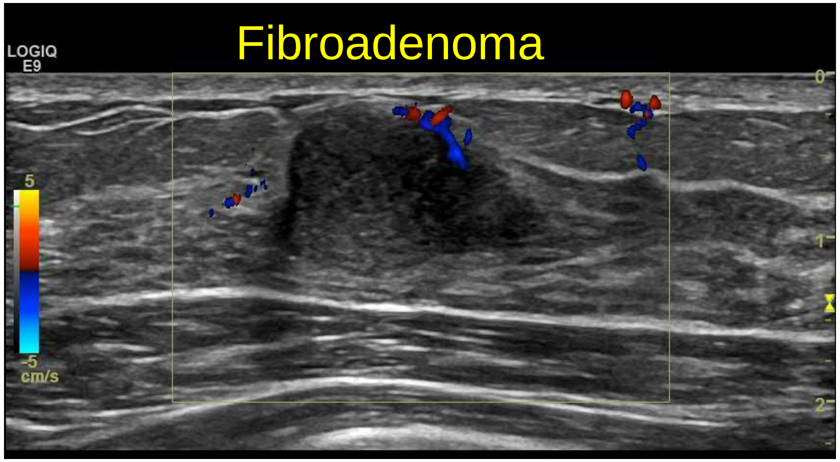


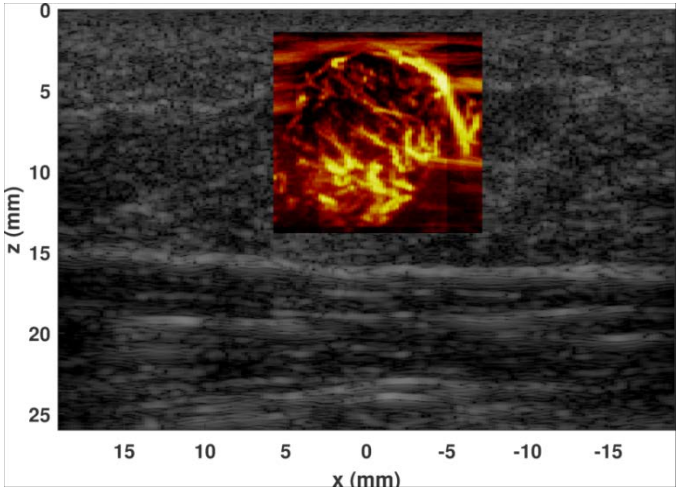
Advanced Tissue
Clutter Filtering [1-4]

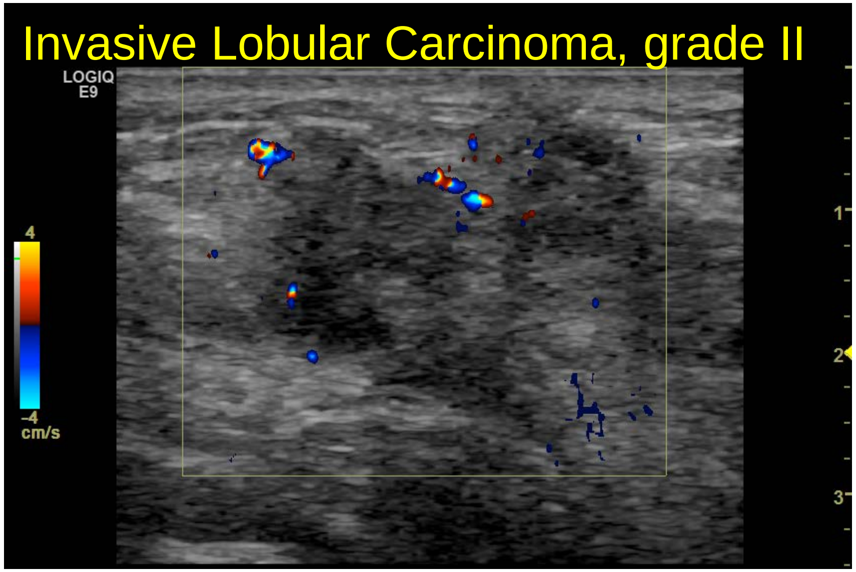


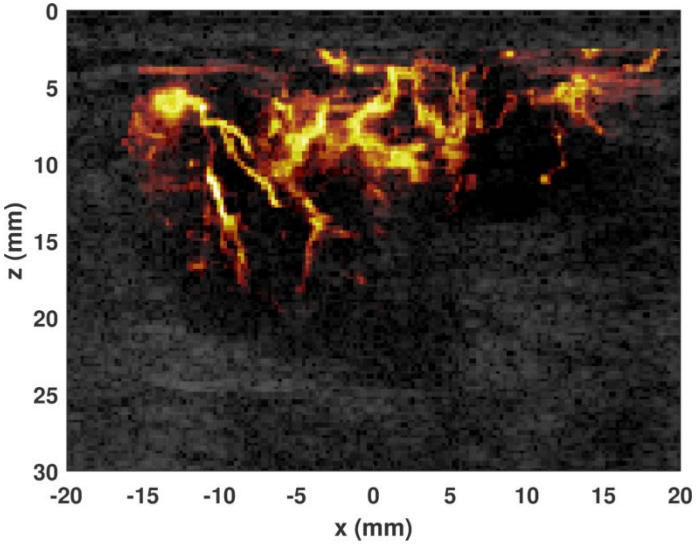
1. P. Song, A. Manduca, J. D. Trzasko and S. Chen, "Ultrasound Small Vessel Imaging With Block-Wise Adaptive Local Clutter Filtering," in *IEEE Transactions on Medical Imaging*, vol. 36, no. 1, pp. 251-262, Jan. 2017.
2. P. Song *et al.*, "Accelerated Singular Value-Based Ultrasound Blood Flow Clutter Filtering With Randomized Singular Value Decomposition and Randomized Spatial Downsampling," in *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 64, no. 4, pp. 706-716, April 2017.
3. P. Song, A. Manduca, J. D. Trzasko and S. Chen, "Noise Equalization for Ultrafast Plane Wave Microvessel Imaging," in *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 64, no. 11, pp. 1776-1781, Nov. 2017.
4. P. Song *et al.*, "Improved Super-Resolution Ultrasound Microvessel Imaging With Spatiotemporal Nonlocal Means Filtering and Bipartite Graph-Based Microbubble Tracking," in *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 65, no. 2, pp. 149-167, Feb. 2018

Conventional Color Doppler VS Ultra-sensitive Microvessel Imaging



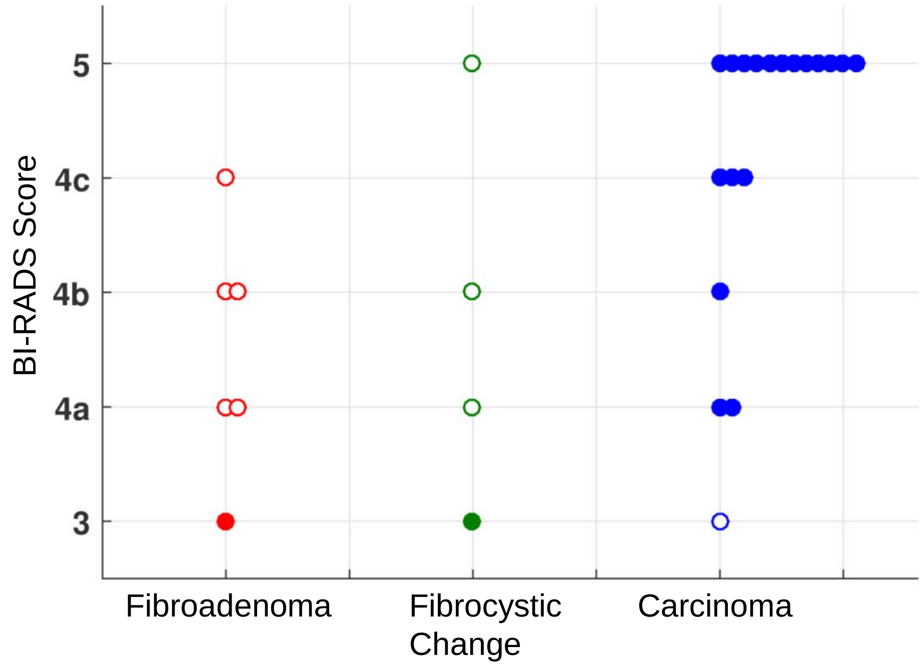






BI-RADS Scores for Benign and Malignant Tumors Based on B-mode and Conventional Doppler Images

Histopathology of masses (n=29)	
Benign	10
Fibroadenoma	6
Fibrocystic breast changes	4
Malignant	17
Invasive ductal carcinoma	13
Ductal carcinoma in situ	1
Invasive lobular carcinoma	4
Invasive mammary carcinoma	1

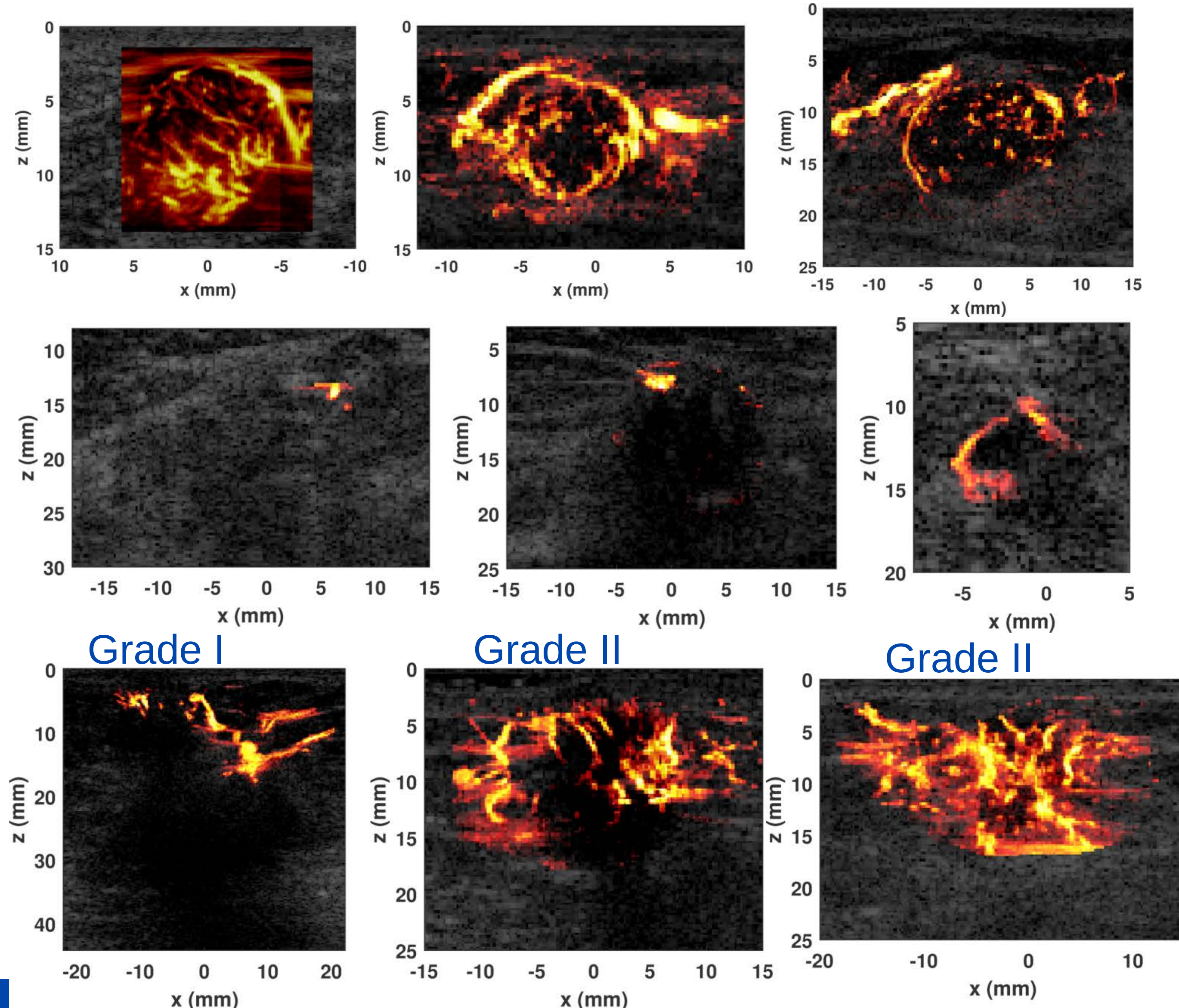


Microvessel Distribution Patterns for Different Mass Types

Fibroadenoma

Fibrocystic
breast changes

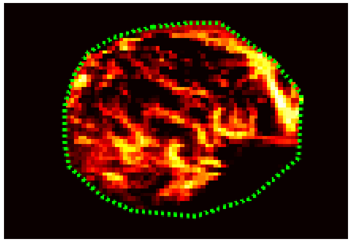
Carcinoma

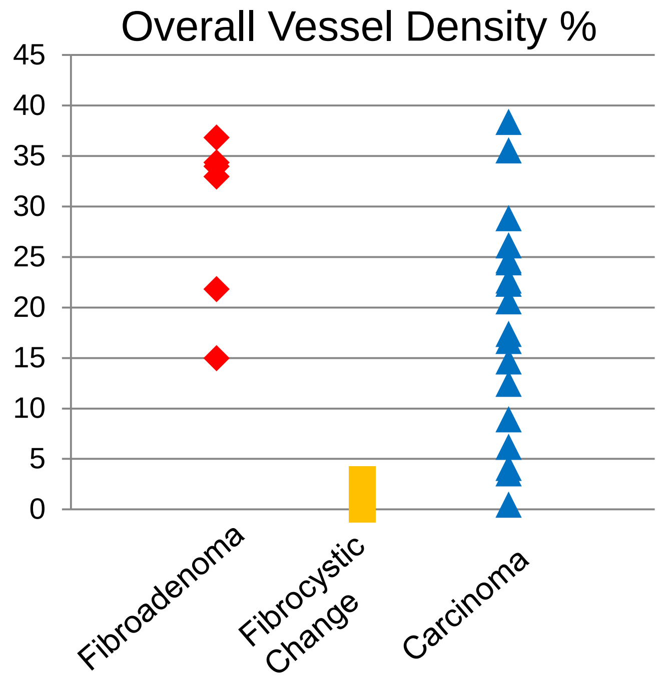


Quantify Ultra-Sensitive Microvessel Images with Commonly Used Parameters

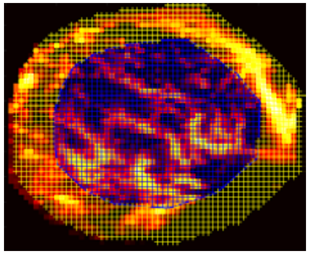
- **Number of Vessels**
  - **Avascular-Hypovascular**
  - **Hypervascular**

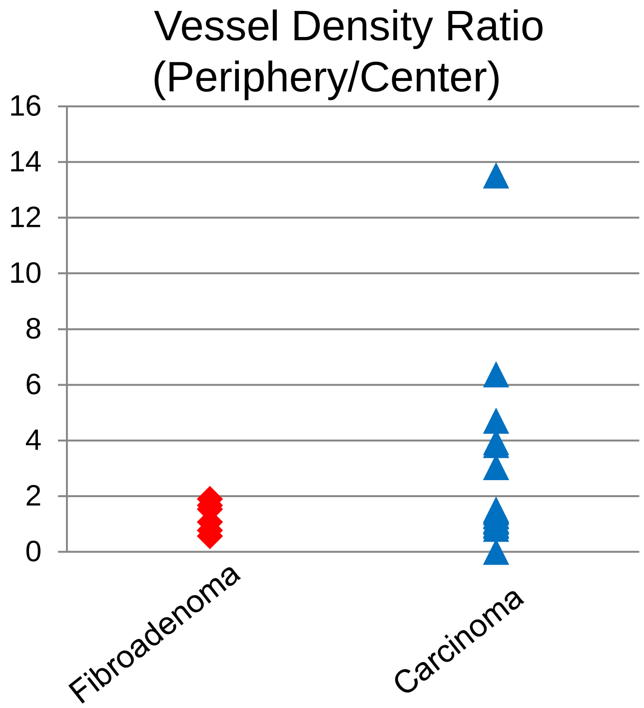
$$\text{vessel density} = \frac{\text{vessel pixels}}{\text{overall tumor pixels}}$$





- **Distribution of Tumor Microvessels**
  - **Central**
  - **Peripheral**
  - **Both**





Use microvessel morphology to upgrade/downgrade mass BI-RADS scores

Microvessel morphologies of different masses

- **Fibroadenoma**
  - **Continuous vessel flow along the mass boundary**
- **Fibrocystic breast changes**
  - **Avascular at center**
  - **Hypovascular at periphery: dot or linear**
- **Carcinoma**
  - **Disordered, irregular branching, penetrating, chaotic morphology**

Regrading BI-RADS based on Microvessel Morphology	
Agree well with benign tumors	-2
Partially agree with benign tumors	-1
No obvious benign or malignant features	0
Partially agree with malignant tumors	+1
Agree well with malignant tumors	+2

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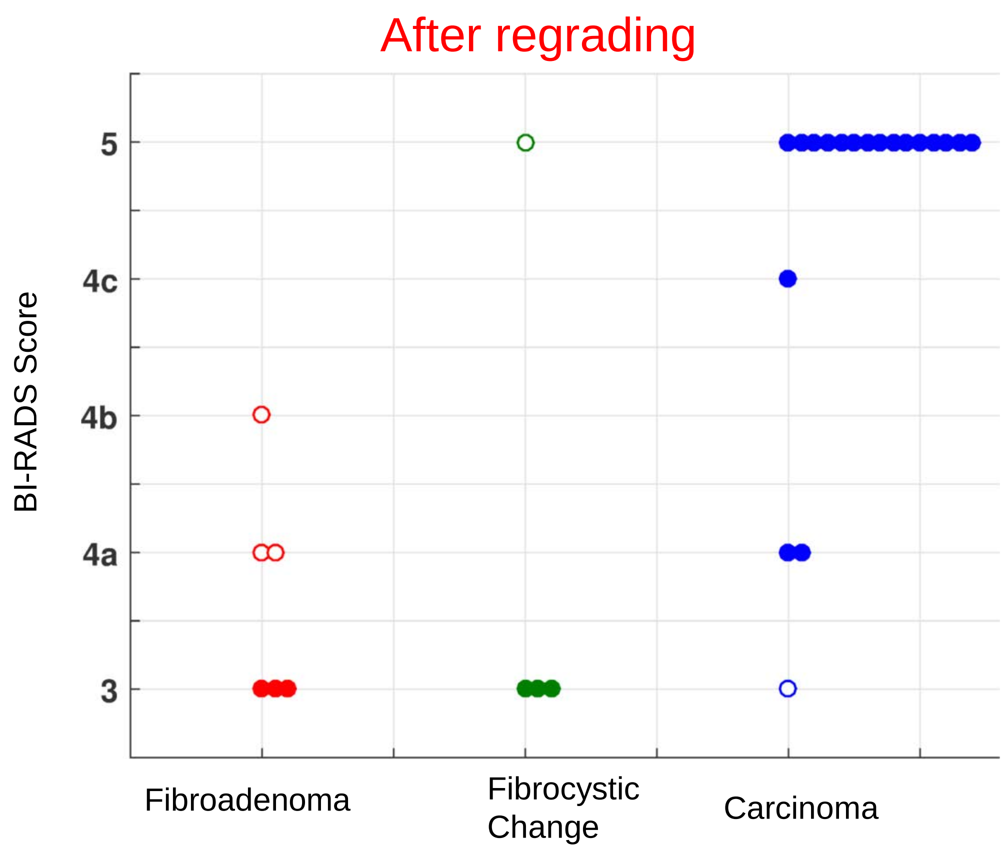
Ultra-sensitive Microvessel Imaging Allows More Accurate BI-RADS



Unnecessary Biopsy reduced by 4 cases

Potentially useful for *early* evaluation of medical therapy response

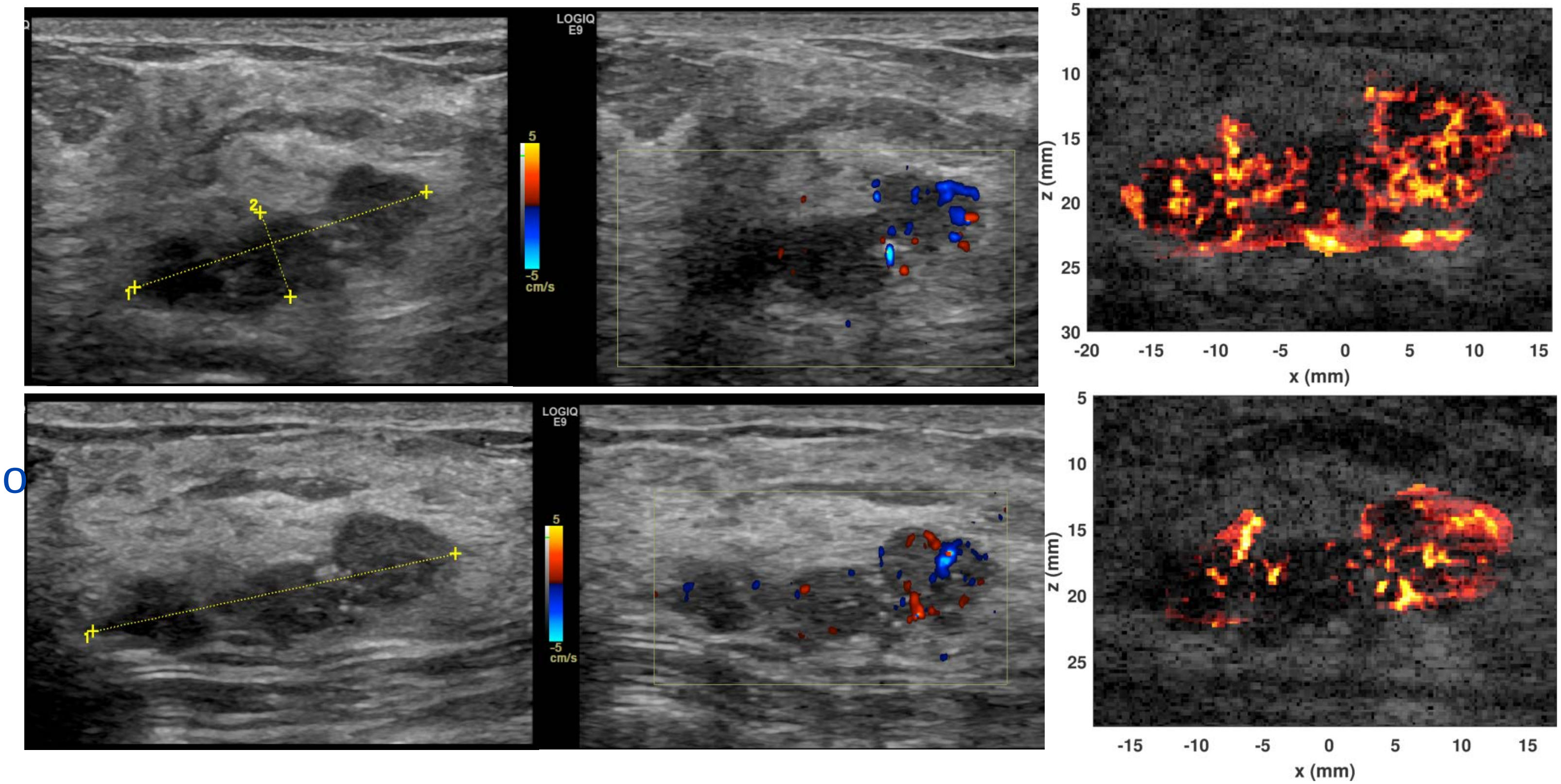
B-mode

Color Doppler

Ultra-sensitive Microvessel Imaging

Baseline

After 1st chemo
Adriamycin
Cytoxan



Questions & Discussion