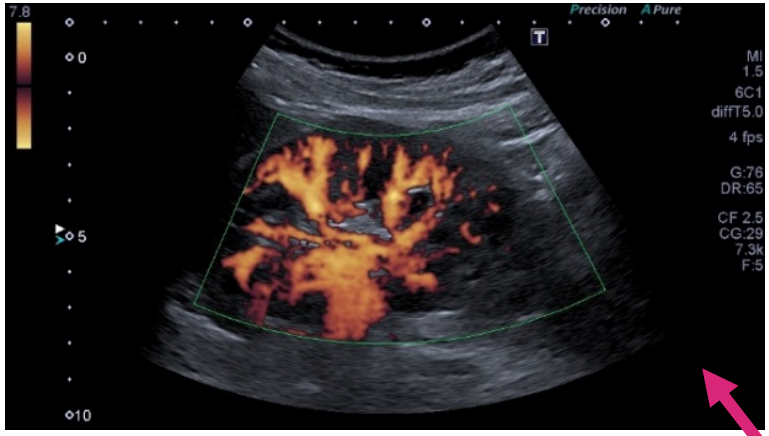
Developement of a new microvascular flow phantom dedicated to ultrasound microvascular flow measurements

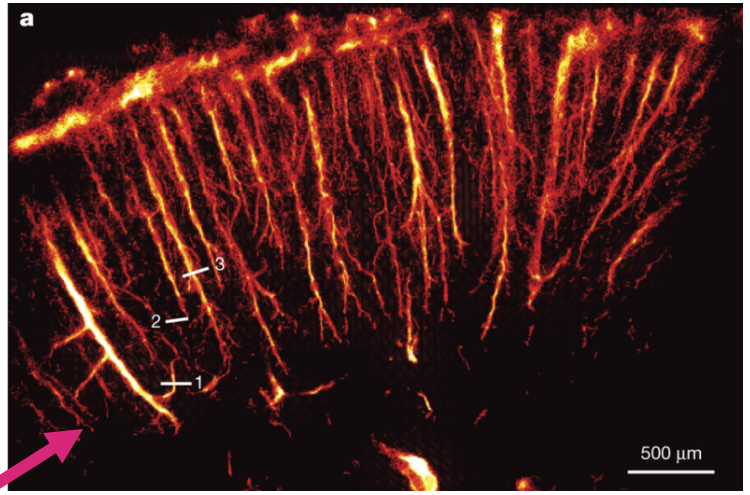
Virginie Grand-Perret[1], Jean-René Jacquet[2], Baya Benatsou[1,3], Georges Willoquet[1], Ingrid Leguerney[1,3], Ayache Bouakaz[2], Nathalie Lassau[1,3], Stéphanie Pitre-Champagnat[1]

[1]IR4M, Univ. Paris-Sud, CNRS, Université Paris-Saclay, Villejuif, France
[2]U930, Univ. Tours, Inserm, Tours, France
[3]Gustave Roussy, Villejuif, France

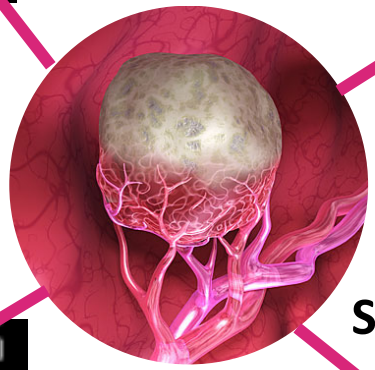
Context : microvascular Doppler imaging modes



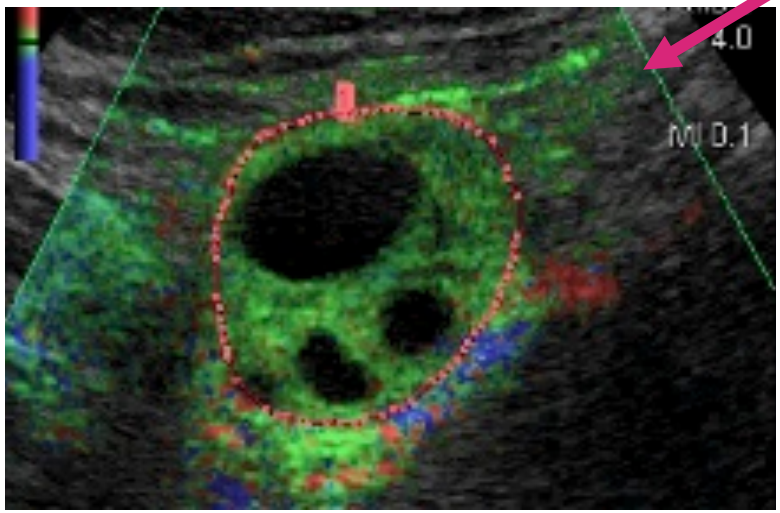
Power Doppler (PD)



Ultrafast super-resolution

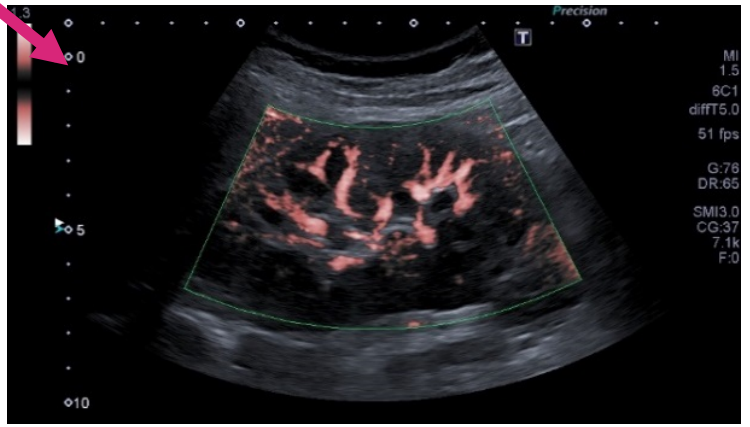


Contrast (DCE-US)



Tumor angiogenesis

Superb Microvascular Imaging (SMI)

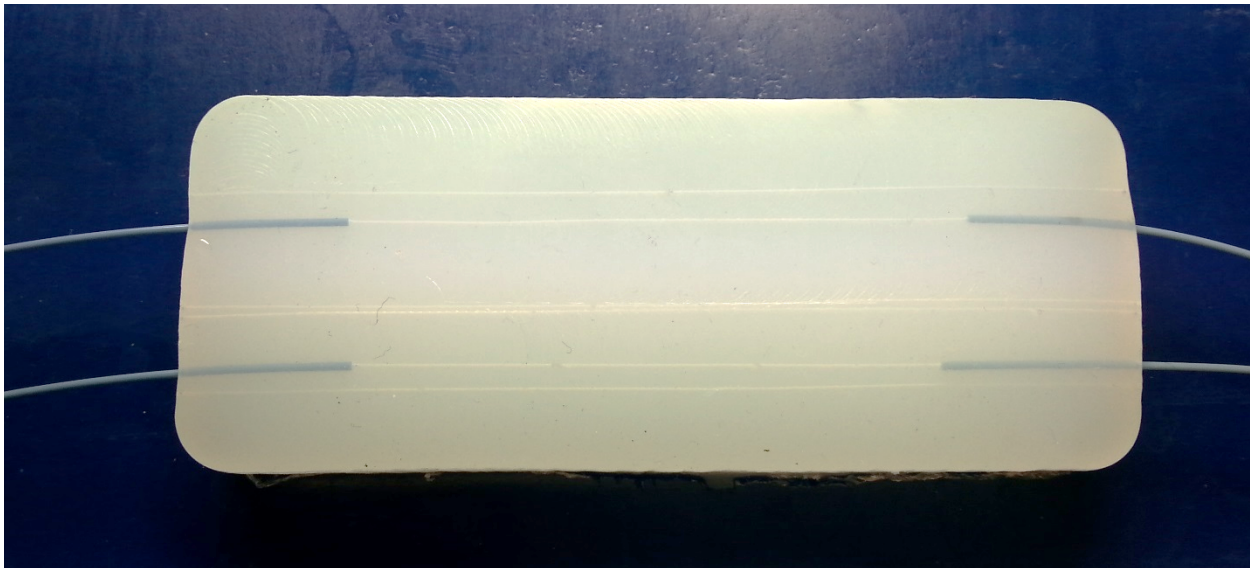


Goals

Evaluate the instrumental performances of these imaging methods :

→ Development of a new generation of microflow phantom

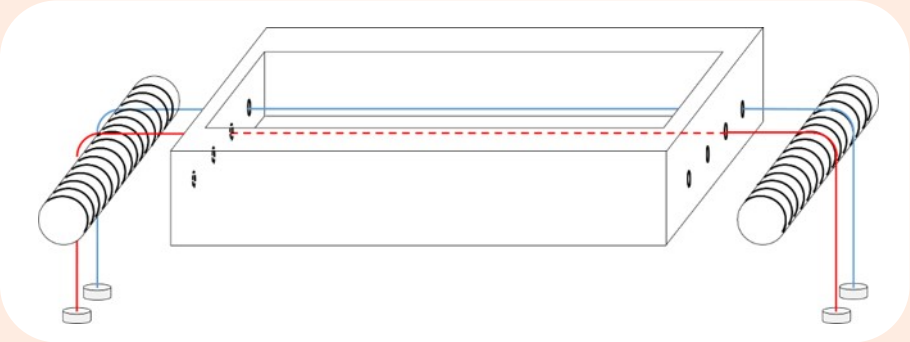
- ➢ robust
- ➢ reproducible
- ➢ Easy-made



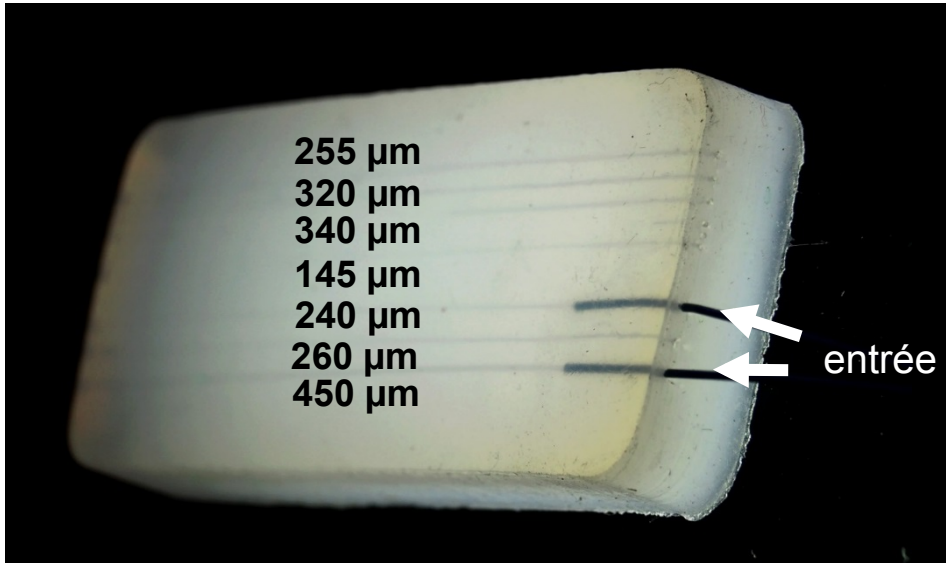
Material & methods (1) : Phantom fabrication

Molding of a silicone material around thin strings to obtain a phantom :

- **Wall less**
- **Thin and circular channels**
- **Ultrasound compatible**
- **Easy to make**



Phantom mold

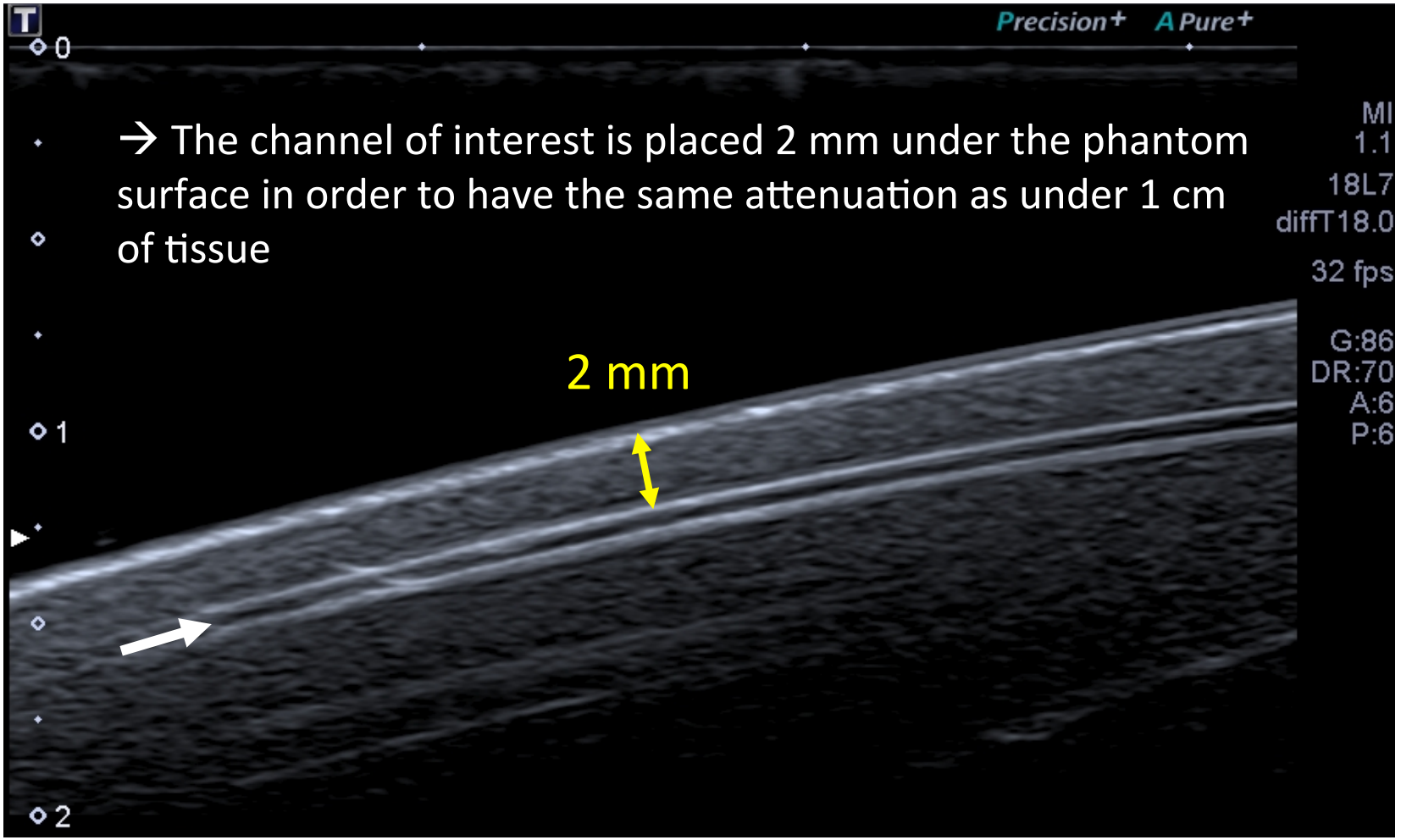


Soft silicone phantom featuring 7 channels of diameters 145 to 450 µm

Material & methods (2) : Acoustic properties

Selected material: Ecoflex 00-30

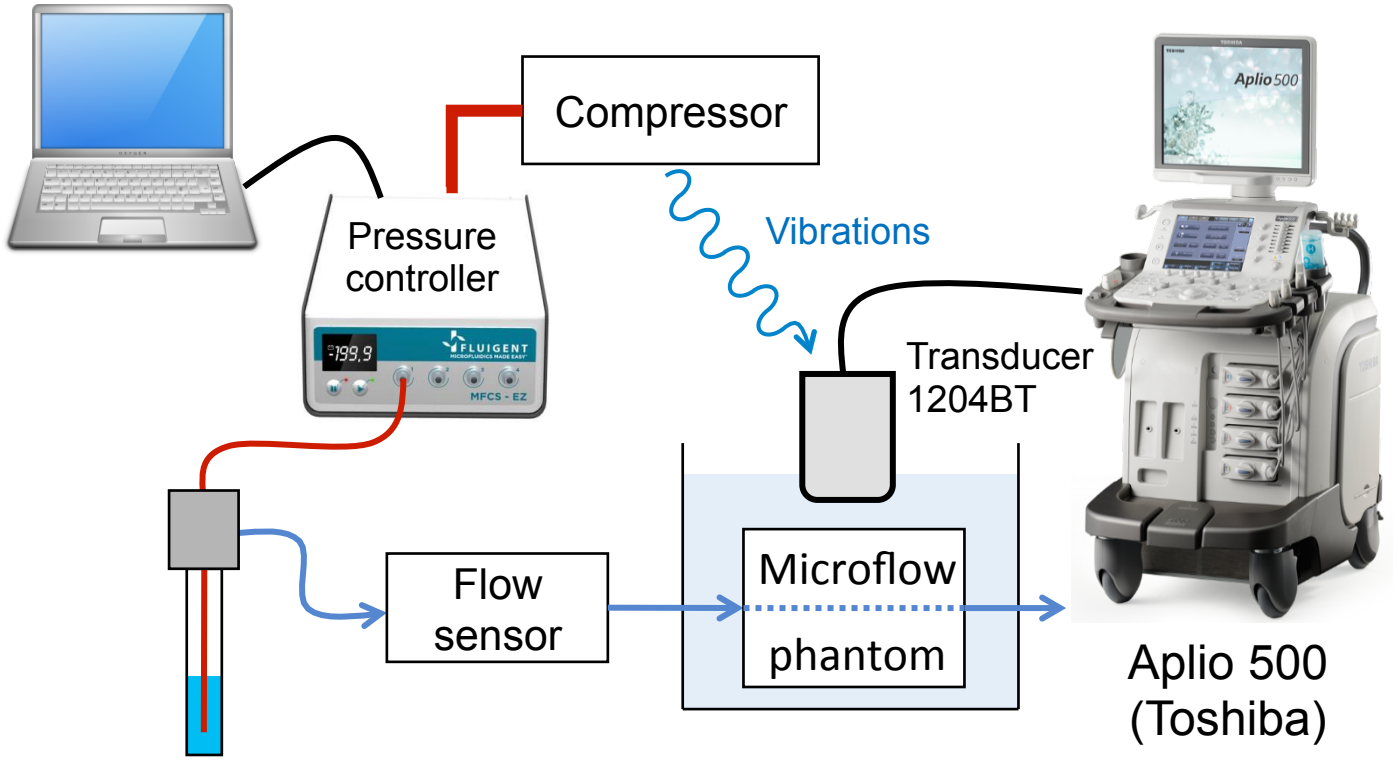
	Ecoflex 00-30	Tissue
Attenuation	-5 dB at **1,4 mm** (@10 MHz)	-5 dB at **1 cm** (@10 MHz)



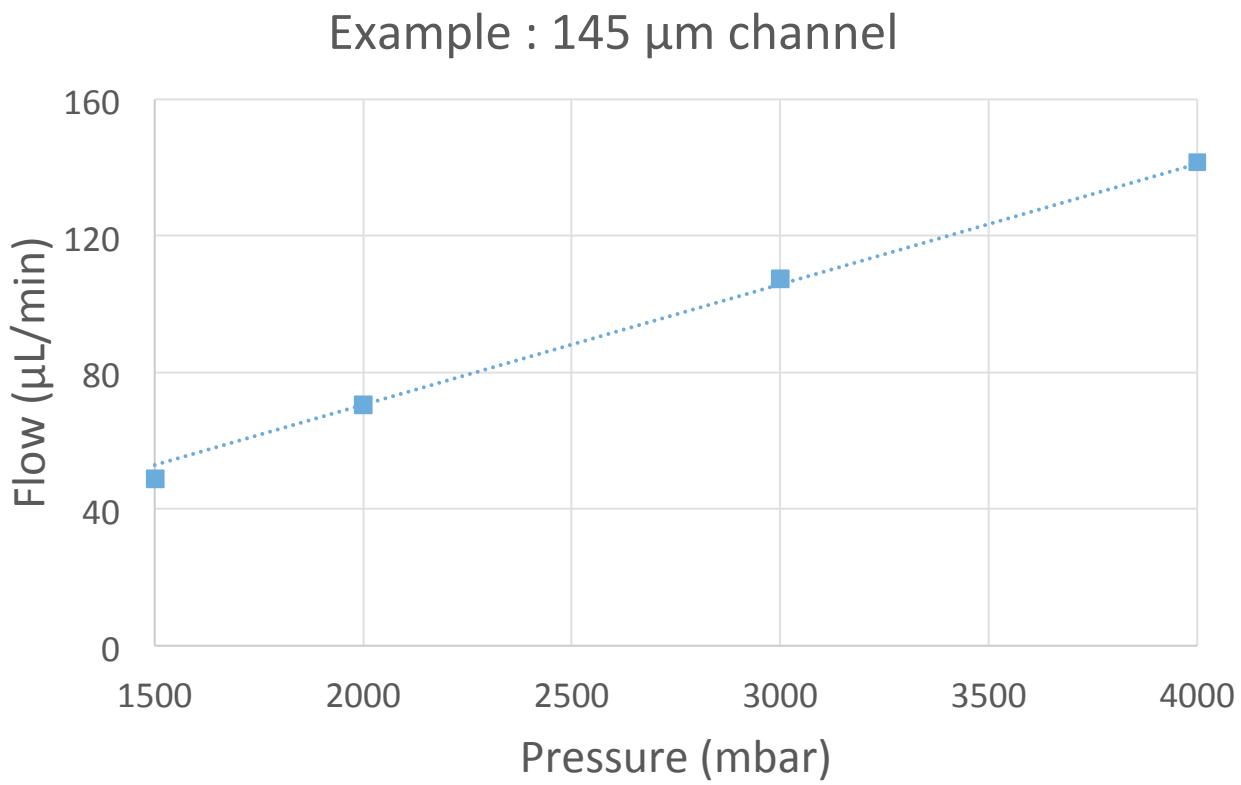
Materiel & methods (3): Experimental setup

Aims :

- Steady flow
- Slow flows
- reproducibility



Material & methods (4): Flow control



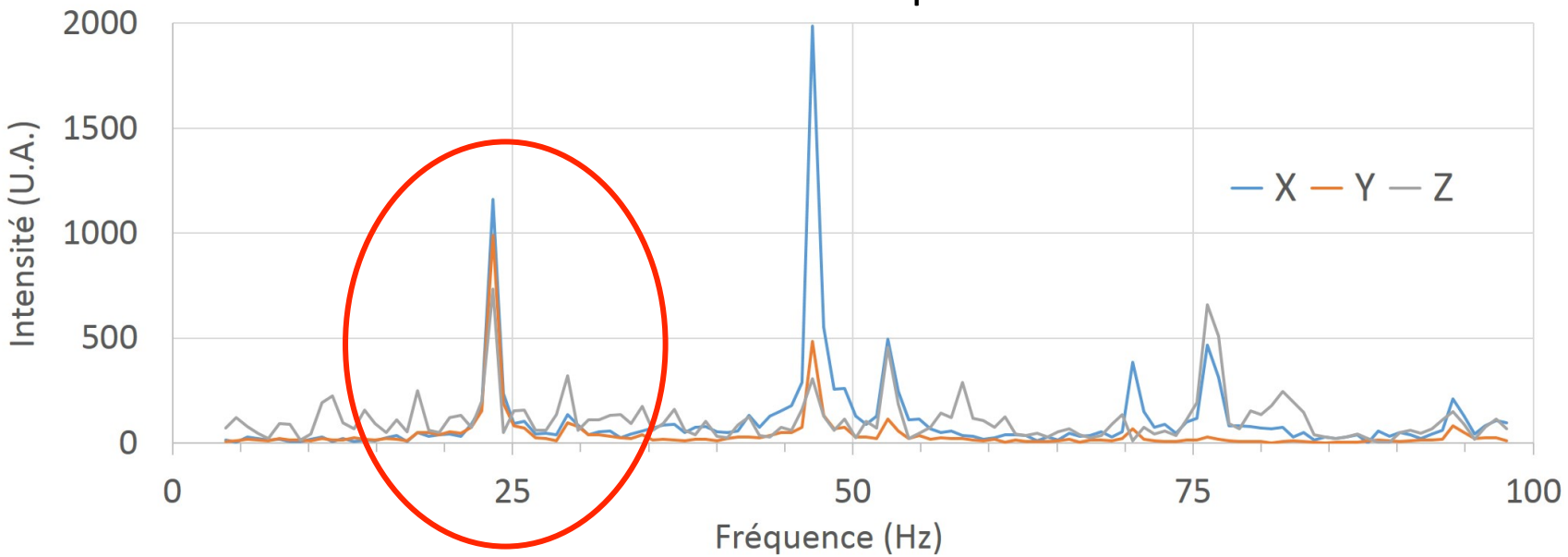
Flow controller → constant and precise pressure

➔ Retrocontrolled constant flow 45-150 µL/min (6-145 mm/s)

Material & methods (5): Vibrations

Aim : mimick physiological artifacts

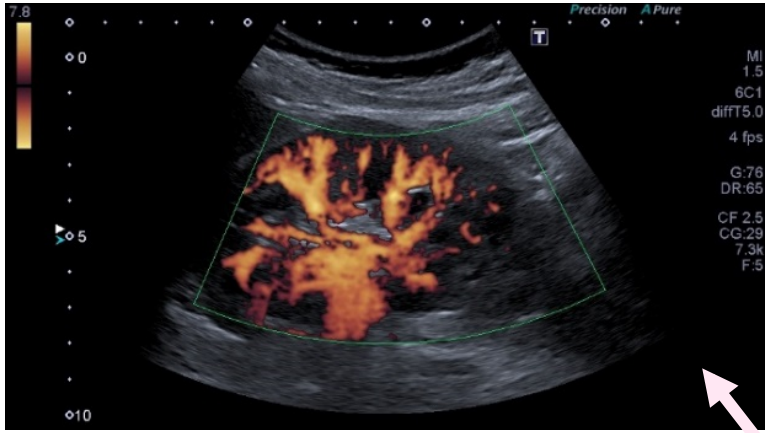
Frequency spectrum of the vibrations in the 3 directions (X,Y,Z) measured on the probe stand



Vibrations:

- Amplitude < 50 µm @ 24 Hz

Material & methods (6): Ultrasound imaging modes



Power Doppler (PD)

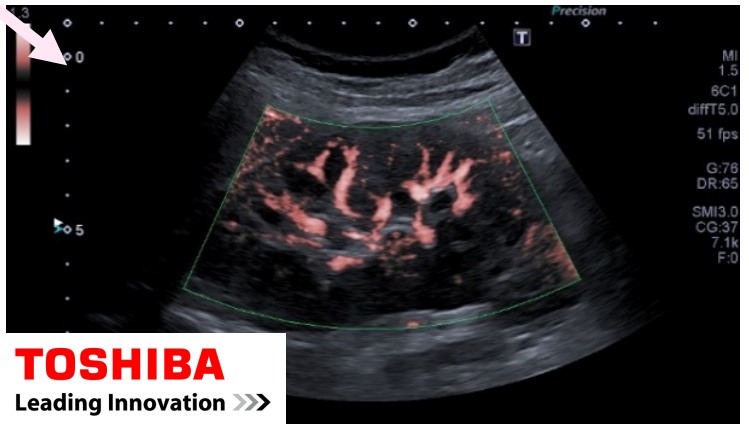
Ultrafast super-resolution

Superb Microvascular Imaging :

- Color (cSMI)
- Monochrome (mSMI)

Contraste (DCE-US)

Tumor angiogenesis

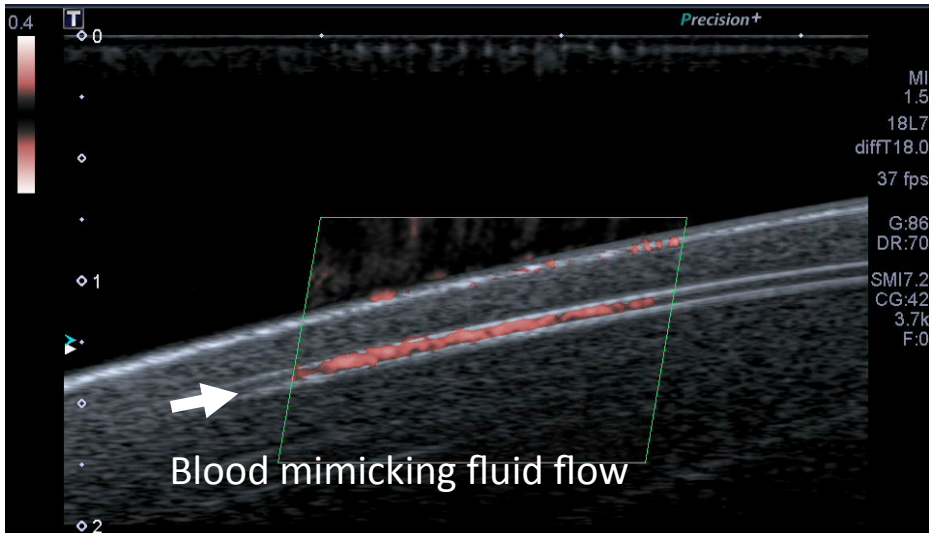


TOSHIBA
Leading Innovation

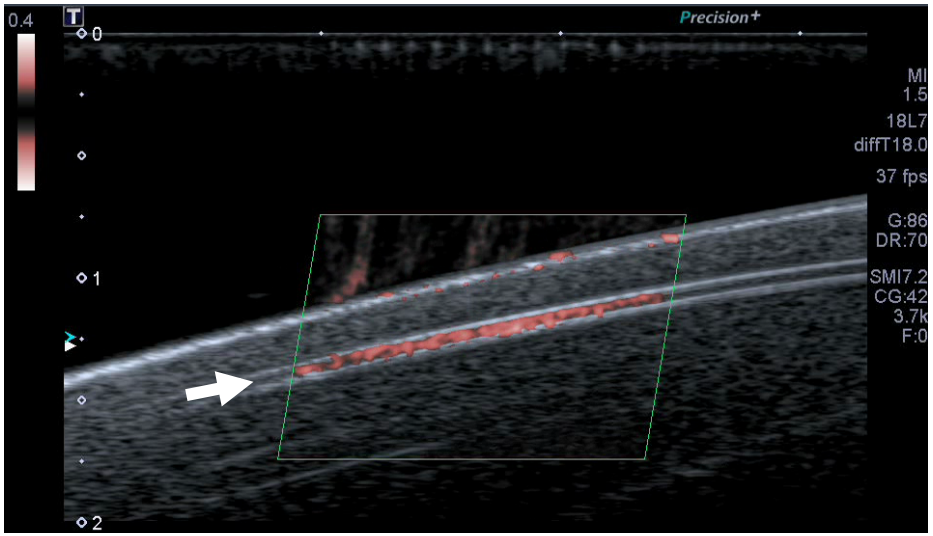
Results : microflow imaging using cSMI (color Superb Microvascular Imaging)

cSMI

Without vibrations



With vibrations



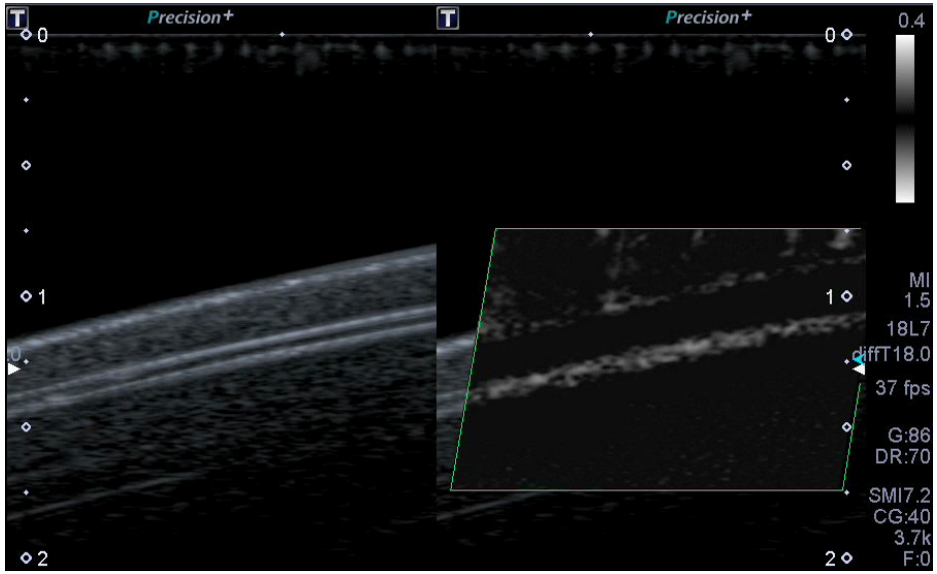
Channel 1 (450 µm) with a flow of 59 µL/min (→ 6 mm/s)

→ Visualization of 50 to 150 µL/min flow for 6 channels (and of > 145 µL/min for the smallest channel), with and without vibrations, **without artifacts**

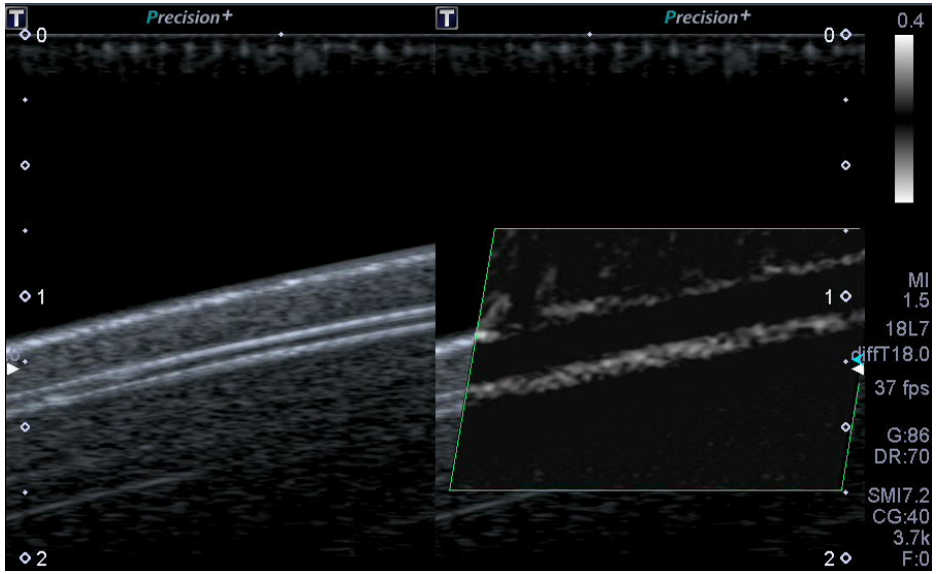
Results : microflow imaging using mSMI (monochrome Superb Microvascular Imaging)

mSMI

Without vibrations



With vibrations



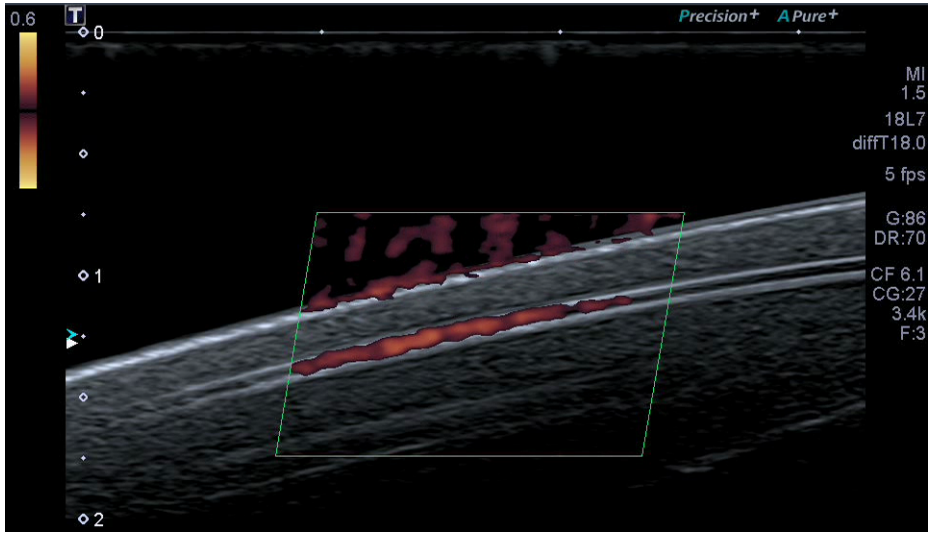
Channel 1 (450 µm) with a flow of 59 µL/min (→ 6 mm/s)

→ Visualization of 50 to 150 µL/min flow for the 7 channels, with and without vibrations, **without artifacts**

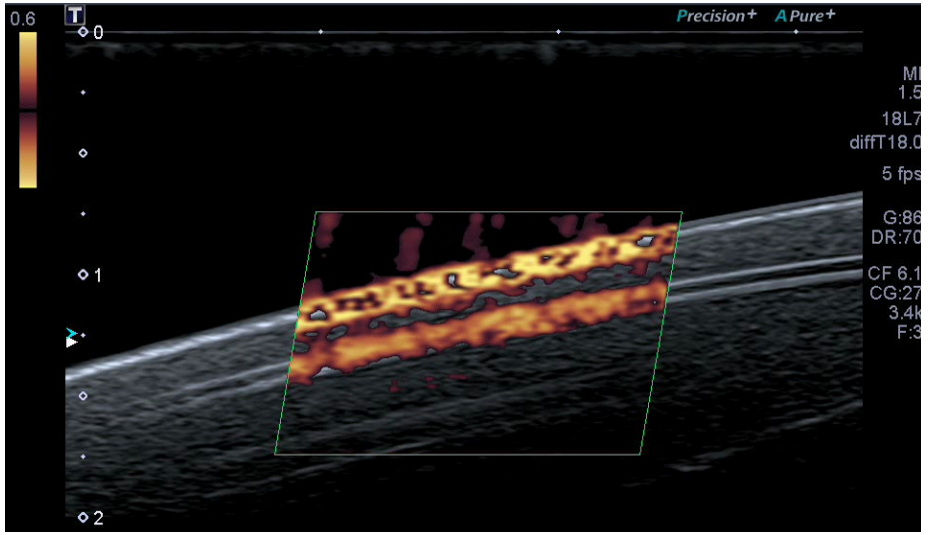
Results : microflow imaging using Power Doppler (PD)

Power Doppler (PD)

Without vibrations



With vibrations



Channel 1 (450 µm) with a flow of 59 µL/min (→ 6 mm/s)

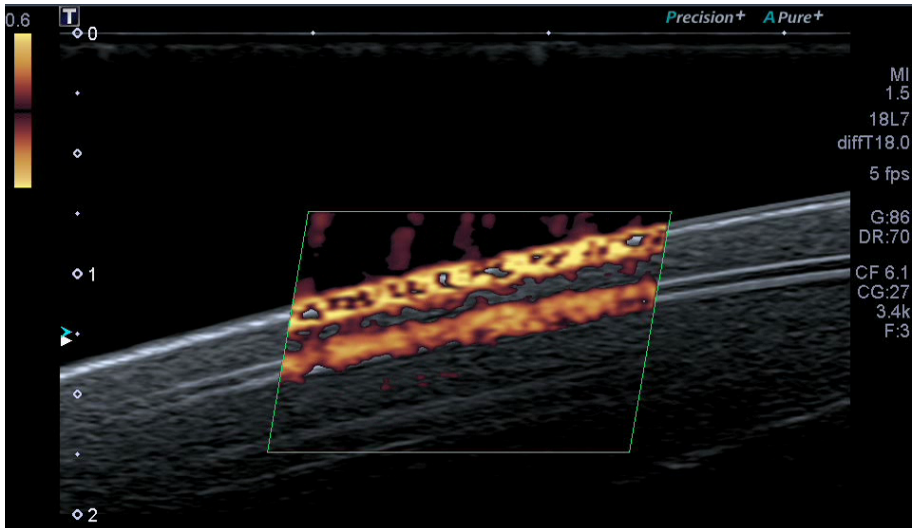
→Visualization of 50 to 150 µL/min flow for 2 channels (>75 µL/min for 3 channels and >114 µL/min for 1 channel), **without vibrations**, **without artifacts**

→**With vibrations** : visualization of a **vascular signal and/or artifacts** → test with no flow (cf next slide)

Results : microflow imaging using Power Doppler (PD) (2)

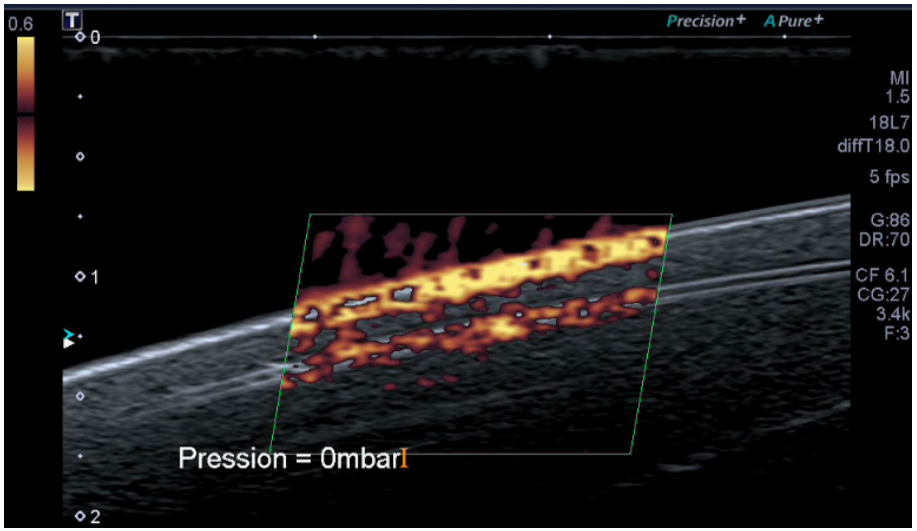
Power Doppler (PD)

With vibrations



Channel 1 **with flow** (59 µL/min)

With vibrations



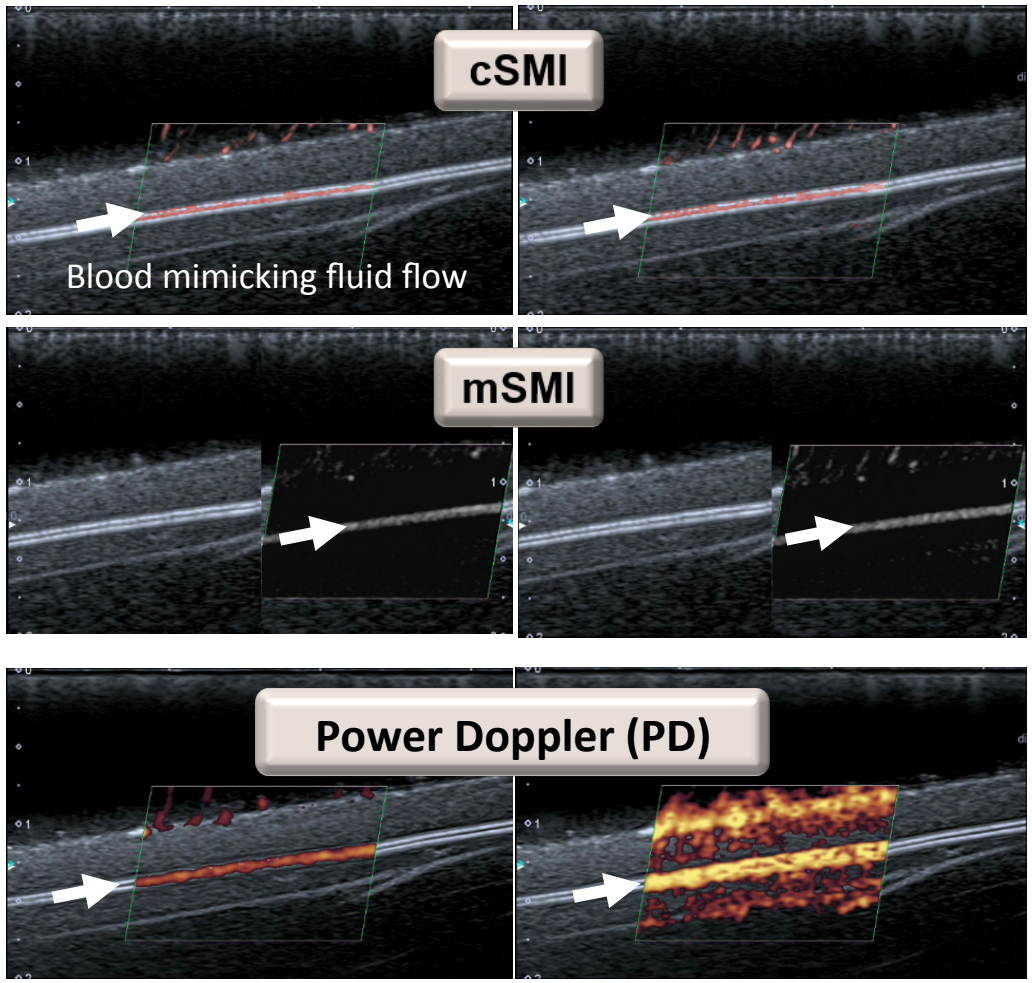
Channel 1 **without flow**

Observed signal does not depend on the presence of a flow

→ Visualization of **artifacts** in presence of **vibrations**

Results : microvascular Doppler imaging modes

Without vibrations **With vibrations**



Artifacts due to vibrations :

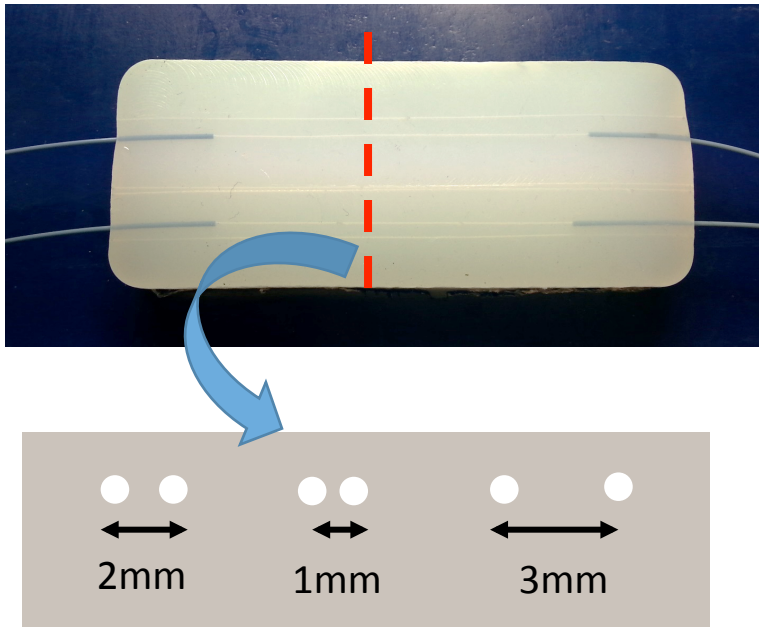
- For SMI and cSMI
- ++ for Power Doppler

Conclusion

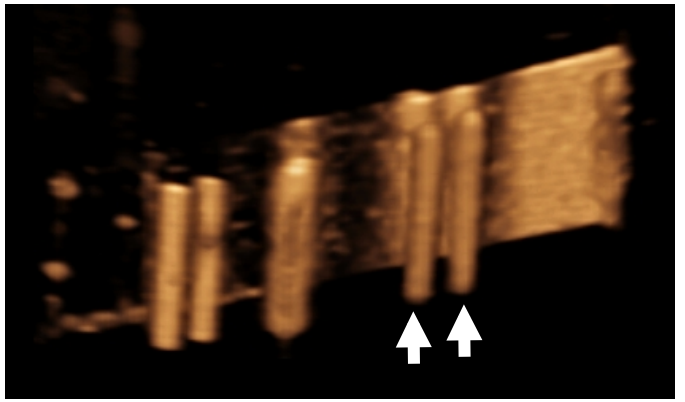
- New phatom : characterization and test tool for *in vitro* studies
  - Easy to make without special equipment
  - Circular channels the size of micro-vessels
  - Flow velocity 6-145 mm/s
- Caracterization of imaging modes:
  - Power Doppler more sensitive to artifacts dues tu physiological movement than cSMI/mSMI
  - Confirms clinical observations
- Future developments:
  - More complex geometry (forks, 3D)
  - Characterization of DCE-US (2D and 4D)

Perspectives : DCE-US 4D characterization

- DCE-US 4D (contrast agent = Sonovue)



Sectional view of the phantom



4D contrast image of the phantom

Thank you for your attention!

References

Lassau N, Bonastre et al., Validation of Dynamic Contrast-Enhanced Ultrasound in Predicting Outcomes of Antiangiogenic Therapy for Solid Tumors The French Multicenter Support for Innovative and Expensive Techniques Study. Invest Radiol 2014;49:794–800.

O'Connor JPB, Aboagye EO et al., Imaging biomarker roadmap for cancer studies. Nat Rev Clin Oncol 2017;14:169–186.

C. Sun, SD. Pye et al., The Speed of Sound and Attenuation of an IEC Agar-Based Tissue-Mimicking Material for High Frequency Ultrasound Applications. Ultrasound Med Biol 38, p 1262-1270 (2012)

Virginie Grand-Perret, Jean-René Jacquet et al., A novel microflow phantom dedicated to ultrasound microvascular measurements. Ultrasonics (soumis 2017)

Contact : virginie.grand-perret@u-psud.fr

UNIVERSITÉ PARIS SUD
Comprendre le monde, construire l'avenir
université PARIS-SACLAY

cnrs

GUSTAVE ROUSSY
CANCER CAMPUS GRAND PARIS

Thank you for your attention!

Directeur : L. Darrasse
Co-directrice : N. Lassau

Equipe 3: *N. Lassau*
S. Pitre-Champagnat
B. Coiffier
I. Leguerney
B. Benatsou
F. Bidault
C. Caramella
S. Ammari
A. Ingels
H. Wang

U930
A. Bouakaz
J.-R. Jacquet
J.-M. Gregoire

Toshiba Medical Systems
S. Gorgeart
T. Yoshida
M. Aoki

M. Jacqueline

Contact : virginie.grand-perret@u-psud.fr