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Adaptive and Quantitative Contrast-free 2D Ultrasound Microvessel Imaging for Evaluation of Tumor Angiogenesis

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INTRODUCTION

Neangiogenesis, the growth of new capillaries form preexisting blood vessels are signs of **infiltrating brain tumor** growth. **Brain tumor surgery** is usually guided by MRI neuronavigation and perioperative echography. However, this imaging techniques do not allowed a clear boundary between tumors and healthy parenchyma. Therefore, **Ultrasound microvessel imaging (UMI)** is a recent **quantitative imaging tool** for tumor characterization that may be useful for perioperative imaging.

OBJECTIVES

→ Develop **new automatic UMI method** which includes:
- new adaptative **robust clutter filtering**
- a new viable **noise biase suppression** which conserves Time Gain Compensation effect
- a new method to **compensate tissue movement** during acquisition

→ This new method will be compared to recent references

→ This new method is used in the frame **ELASTOGLI** clinical project

METHOD

Echographic parameters

Frequency (MHz)	PRF (kHz)	Tilted plane waves	Duration of acquisition (s)	Resolution (um) (width/length)	Ultrafast ultrasound device
5.625	3	[-5°, 0°, +5°]	1	200/140	Aixplorer Supersonic Imagine (France)

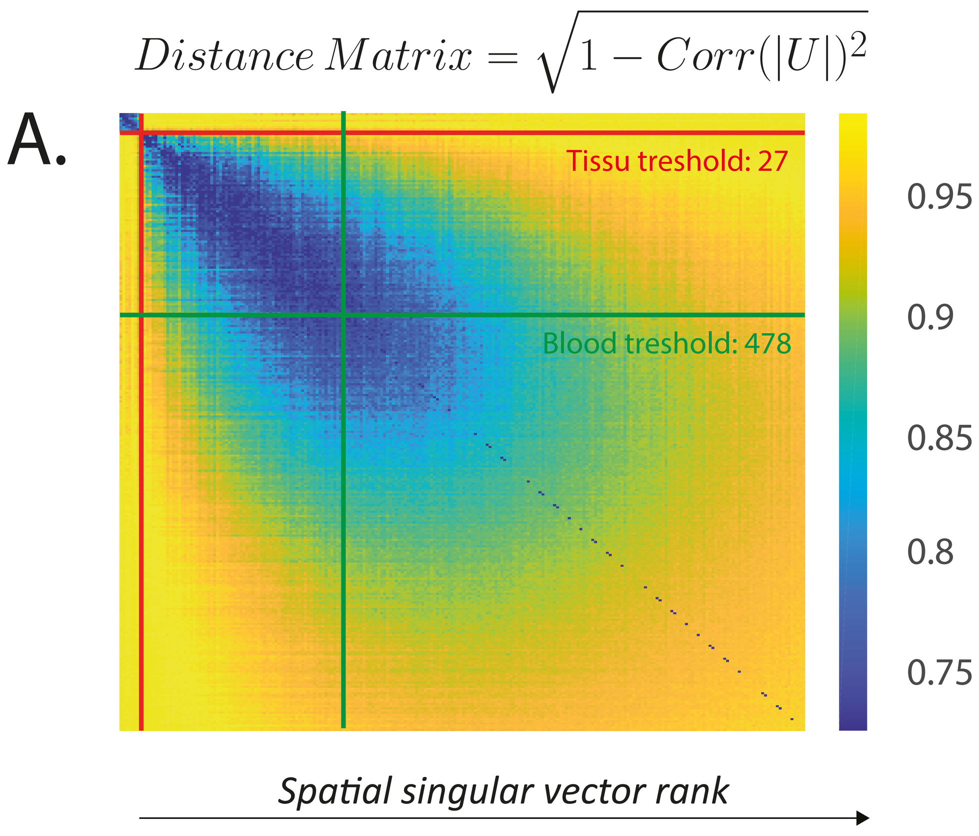
→ In Quadrature complex data are obtained after SSI beamforming from perioperative imaging during brain surgery

Step 1 : Hierarchical Clustering

Singular Value Decomposition ↔ $IQ_{data}(x,z,t) = U\lambda V$

$$Distance\ Matrix = \sqrt{1 - Corr(|U|)^2}$$

A.



B.

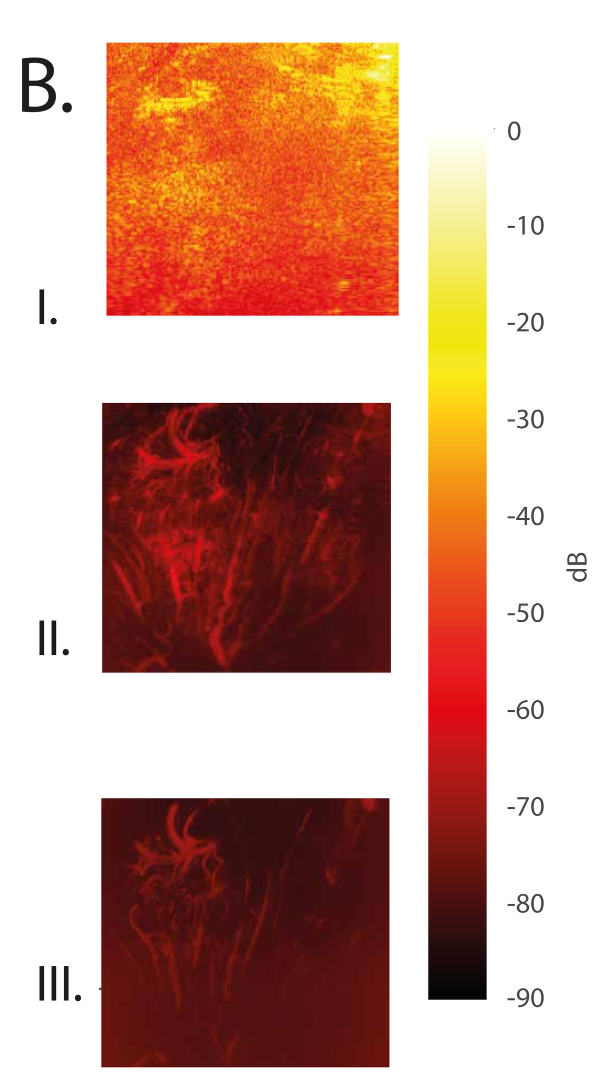


Figure 1: *A. Distance matrix calculated from spatial singular vectors basis U, tresholding is obtained with hierarchical clustering; B. Power Doppler of the three subspace resulting from clustering: I. Tissue, II. Blood, III.Noisy blood.*

Step 2 : Noise bias compensation

Figure 2: *Noise biass suppression: I. Power Doppler of blood + noisy blood , II. Noise profil obtained from half lower energetic spatial singular vectors with median filtering and fft2, III. Denoised blood obtained by substraction (I) - (II).*

Step 3 : Blind deconvolution

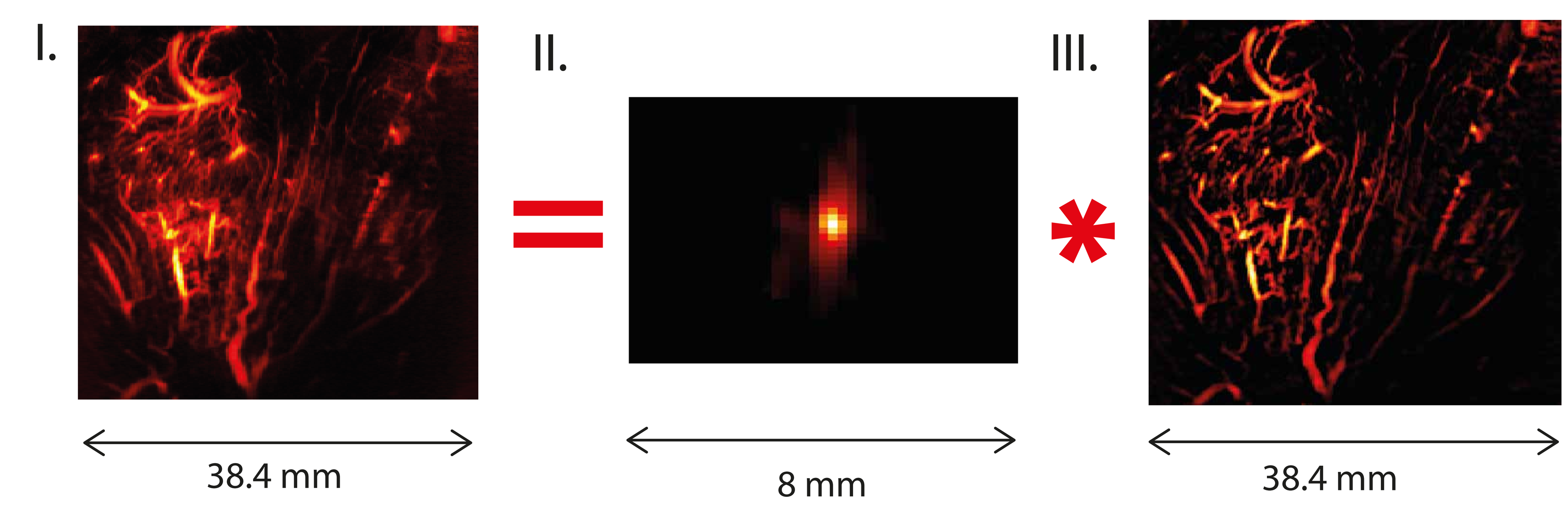


Figure 3: *Blind deconvolution: I. Denoised blood, II. psf obtained with Lucy Richardson algorithm from (I) , III. deconvolved matrix with Wiener filter from (I) and (II)*

RESULTS

Qualitive metrics

→ Calculted with the 47 first **ELASTOGLI** echographies of ELASTOGLI

$$CNR = \frac{\overline{Signal_{dB}} - \overline{Noise_{dB}}}{\sigma_{Noise_{dB}}}$$

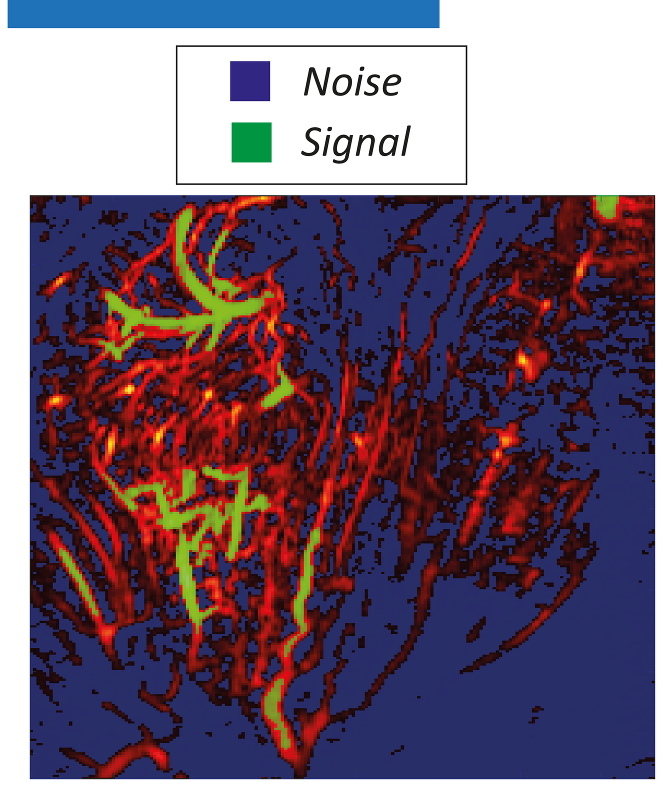
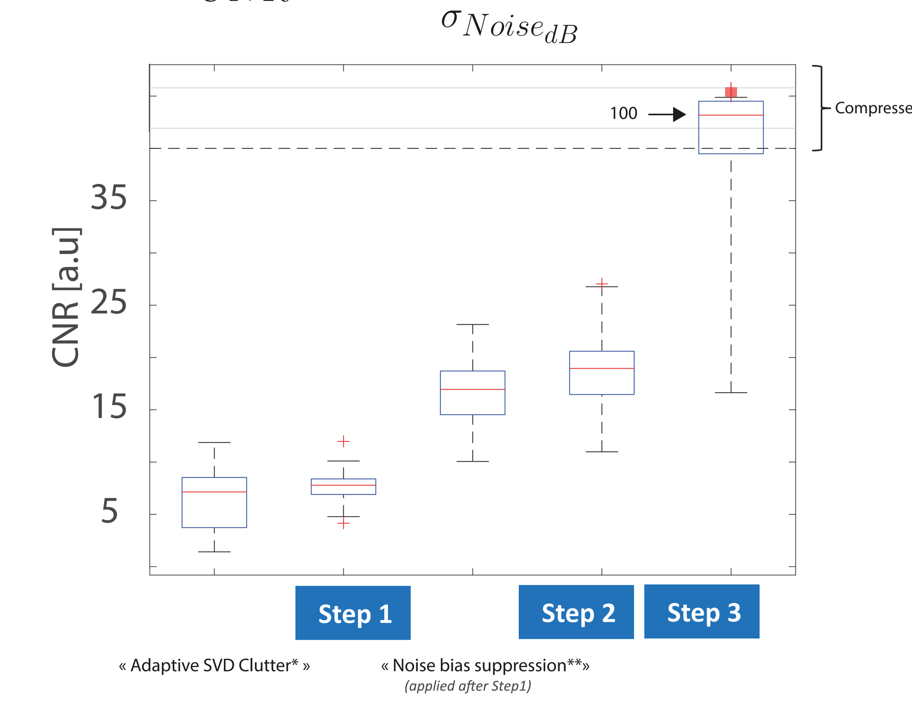


Figure 4: *Automatic segmentation based on tresholding*



*Baranger, Jérôme, Bastien Arnal, Fabienne Perren, Olivier Baud, Mickael Tanter, et Charlie Demené. « Adaptive Spatiotemporal SVD Clutter Filtering for Ultrafast Doppler Imaging Using Similarity of Spatial Singular Vectors ». IEEE Transactions on Medical Imaging 2018
**Nayak, Rohit, Mostafa Fatemi, et Azra Alizad. « Adaptive Background Noise Bias Suppression in Contrast-Free Ultrasound Microvascular Imaging ». Physics in Medicine & Biology 2019

Quantitative metrics

→ Metrics defined in Huang, Chengwu, Matthew R. Lowerison, Fabrice Lucien, Ping Gong, Diping Wang, Pengfei Song, et Shigao Chen. « Noninvasive Contrast-Free 3D Evaluation of Tumor Angiogenesis with Ultrasensitive Ultrasound Microvessel Imaging ». Scientific Reports 2019

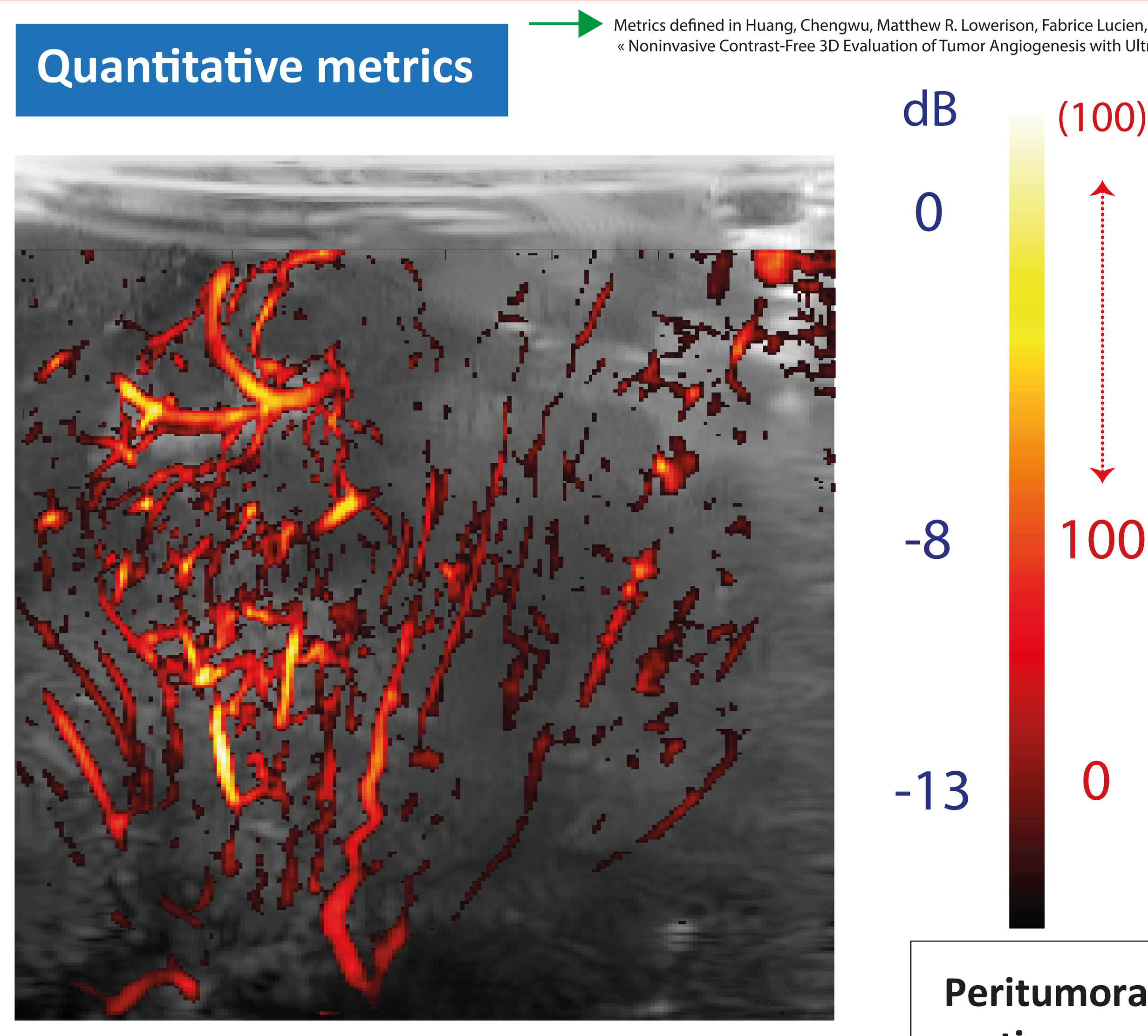


Figure 4: *Bmode and Power Doppler*

Fractionnal Moving Blood Volume (%)

$$VI = \frac{Area_{vessel}}{Area_{image}}$$

	VI(%)	FMBV(%)
Peritumoral tissue	5,5	2

CONCLUSIONS

→ The proposed **new automatic UMI** superior show superior CNR compared to reference
- clutter filtering is more robust than reference (works on all ELASTOGLI patients)
- noise biase suppression is more viable as conserve TGC factor

→ This method will allow to assess quantitative parameters (**vascularization index** and **fractional moving blood volume**) to differentiate **infiltrating tumor** from **tumor** and **healthy parenchyma** among **ELASTOGLI** patients