1. Ultrasensitive Doppler

- Ultrasensitive power Doppler (µPD) ultrasound (US) has become an alternative for microcirculation imaging (Bercoff et al., IEEE UFFC, 2011)
- A µPD image is obtained as the square of the clutter filtered Doppler ensemble (CFDE), where clutter filtering is performed using a singular value decomposition (SVD) thresholding approach (Déméné et al., IEEE TMI, 2015)
- The µPD image can be used to calculate the resistivity index (RI), which is of great importance in clinical applications

CHALLENGES:
- µPD in deep tissues (kidney and liver) is greatly affected by time gain compensation (TGC) effects, which drastically affect blood flow signals in deeper areas, making it difficult to visualize blood vessels in these regions
- Compensation for TGC effects by the equalization approach normally assumed that background noise is homogenous over channels
- AIM:
  - Develop an alternative equalization method where the background noise is estimated considering inhomogeneity over the channels, thus obtaining an improved µPD image that is used to obtain a RI map

2. Automatic computation of RI map using ultrasensitive Doppler

- TGC(x) is estimated from the PO image by using a combination of a median filter and a 2D Gaussian filter
- Vessels are detected at each depth using a thresholding approach

3. Data acquisition and processing

- Acquisitions were performed out by an experienced radiologist in a pilot study on 11 patients at Necker Hospital (ethical protocol APHP N°2018.037)
- RI measurements with the clinical and proposed methods were performed on the same day and in the same region of the transplanted kidney
- The ultrafast ultrasound sequence consisted of 2 angles acquired at 4000 Hz during 1s (PRI = 2000 Hz) by using an ultrafast ultrasound device (Aploigner V12 (SonicVision, Aix-en-Provence, France) with a linear probe S10-2 (central frequency 5 MHz, pitch 0.2 mm, 113 elements)
- Acquired data were post-processed by using Matlab software (version 2020b)

4. Preliminary Results

- Power Doppler Image
- Clinical vs Proposed method
- Improved visualization of small vessels
- In clinical is not possible to obtain a RI map, but the RI at certain points is lower than 0.4 dB
- Relative errors in RI were less than 10% (3 measurements)

Current challenges:
- The method to compensate for aliasing effects fails in cases of very low SNR (< 3 dB), leading to a biased estimation of RI values
- The RI map must be post-processed to filter out signals of non-pulsatile flows (RI values less than 0.2) and estimates of signals with low SNR
- The minimum conditions for obtaining reliable RI values in terms of SNR have not been tested, since the comparison with clinical measurements was performed at points whose SNR was higher than 8 dB

5. Conclusions

- An ultrafast ultrasound Doppler sequence has been developed and further improved by using patient acquisitions
- PD results were improved by applying compensation for TGC effects
- Improved PD images were obtained as compared with other methods that consider homogeneous over channels
- Preliminary results were obtained from patients on vascularization, and resistivity index, which were evaluated using clinical measurements

6. Future works

- Verification of the limited conditions for obtaining reliable RI values will be carried out by simulations and in vitro experiments using tissue-mimicking phantoms of blood flow
- Further processing of the RI map will be developed to detect only pulsatile flow and discard values obtained from very low SNR signals

This study was supported by “Bettencourt Schueller foundation” under the project name “PERFUSION, in the biomedical engineering chair from “Ecole Polytechnique”