

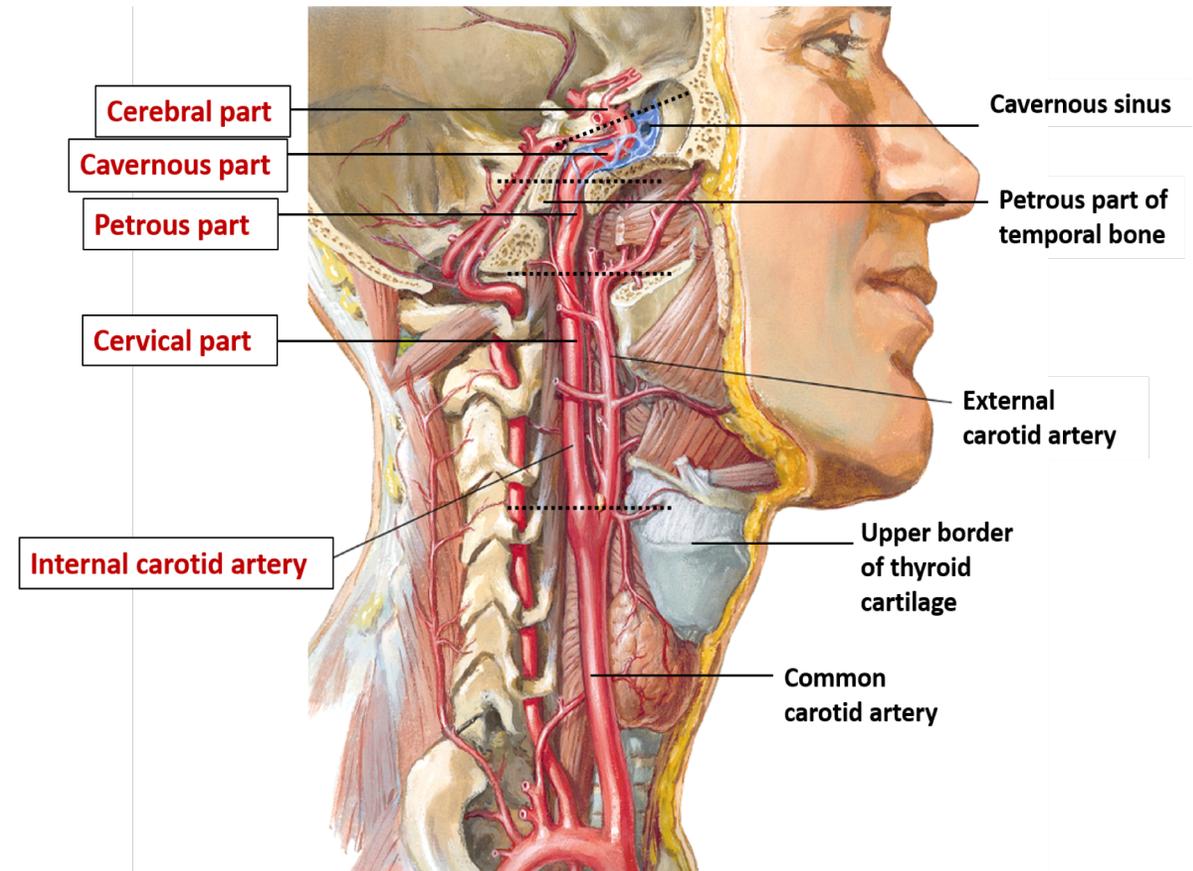
Facoltà di Ingegneria  
Dipartimento di Ingegneria Civile e Architettura (DICAr)

# ANALISI QUANTITATIVA SU ECOGENICITA' DI MODELLO CAROTIDEO STAMPATO IN 3D

candidato: **Armando Oscar Rossi**  
relatore: **prof. Michele Conti**  
correlatore: **dott.ssa Giulia Matrone**

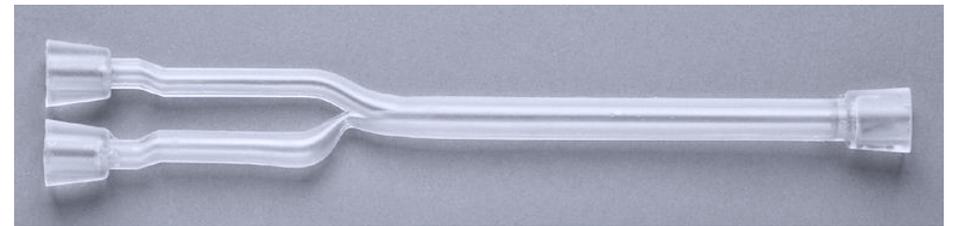
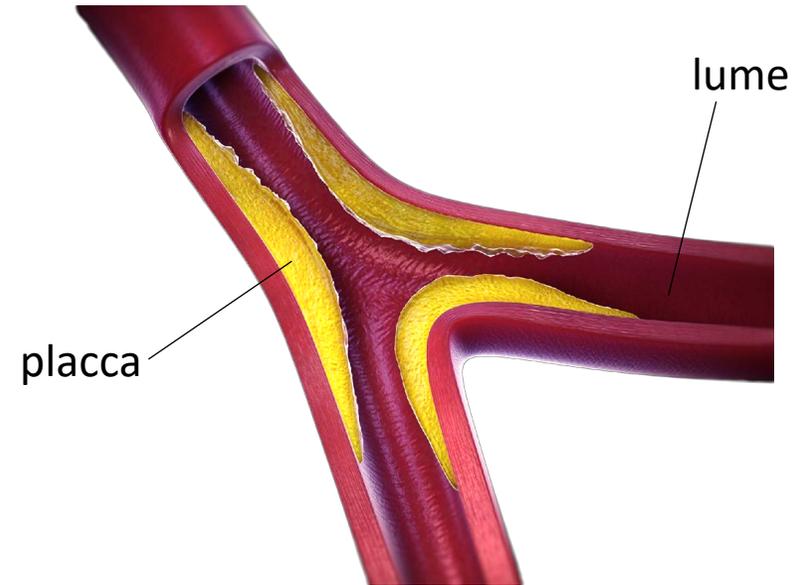
# Arteria carotide

- Irrora il sistema nervoso centrale e le strutture facciali
- La carotide comune origina dall'arco aortico
- Nel distretto cervicale si biforca in *esterna* e *interna*
- Sede preferenziale per formazione di placche aterosclerotiche → stenosi



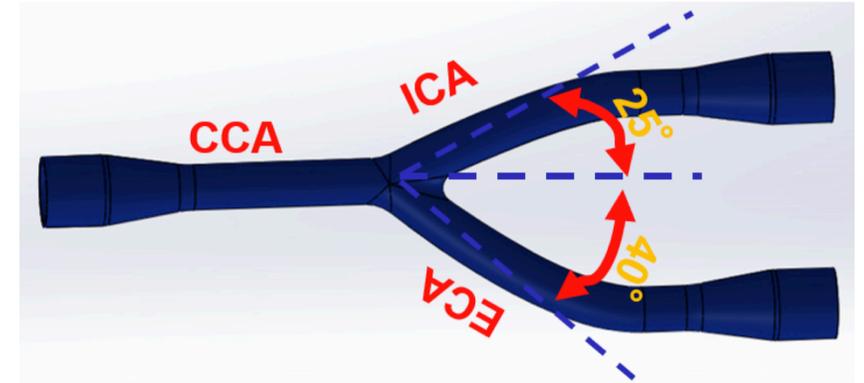
# Placca e studio biomeccanico

- Stenosi carotidea: restringimento del lume dell'arteria carotide.
  - Correlata a rischio di Ictus e TIA
  - Necessari studi diagnostici
- Uno degli approcci è quello di realizzare un modello *in vitro*
  - Phantom basato su misure reali e stampato con materiali complianti

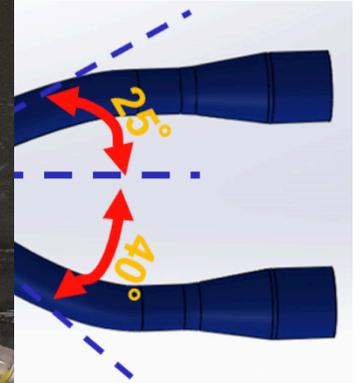
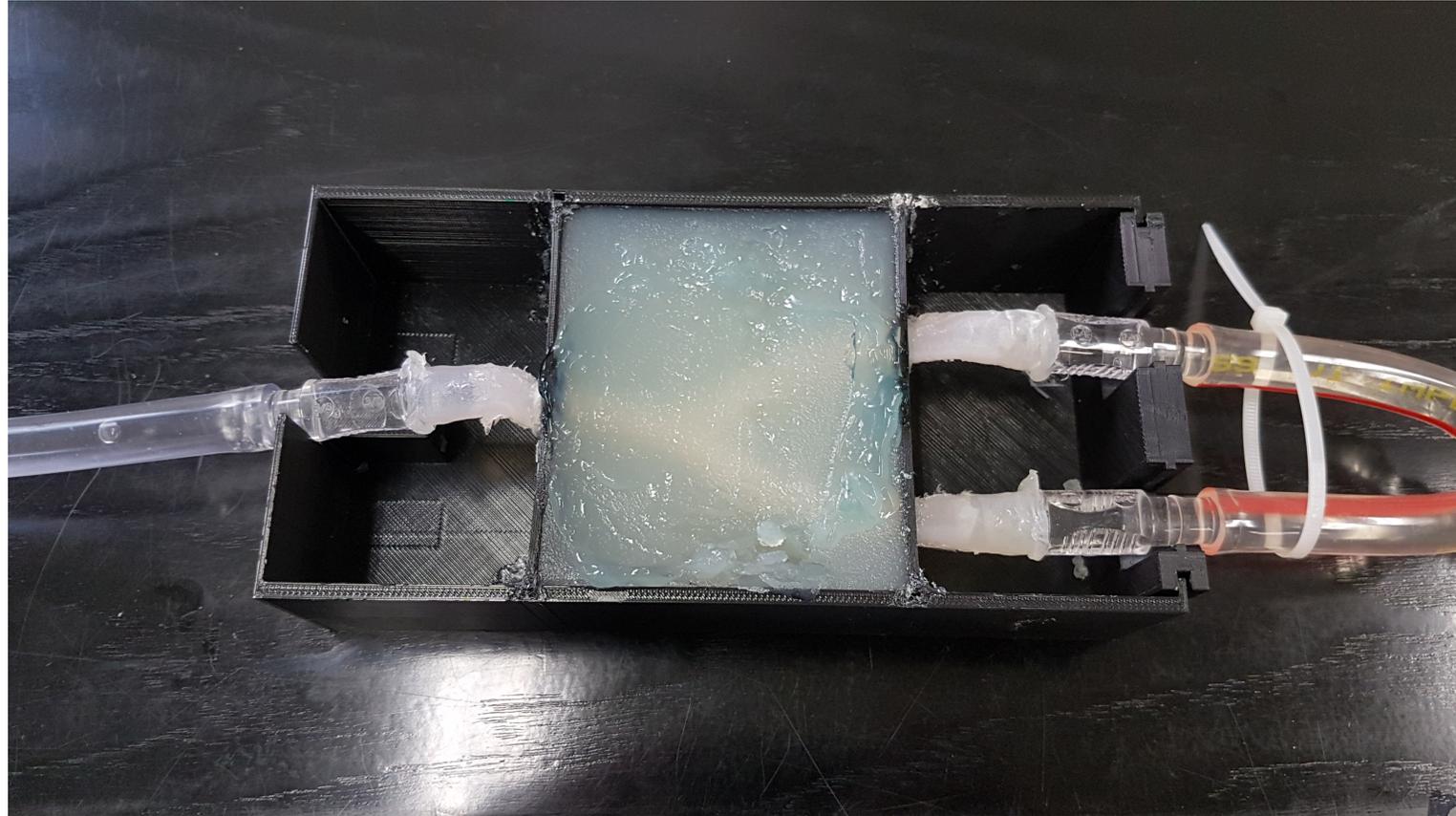


# Modello di biforcazione

- Modellizzazione con software CAD
  - Dimensioni reali ottenute da riferimenti in letteratura
    - Asimmetria della biforcazione
- Realizzazione tramite stampa 3D
  - Stampante *Objet 260 Connex3*
  - Materiali complianti
    - *TangoPlus*
    - *VeroCyano*
    - *Agilus30 Pro*

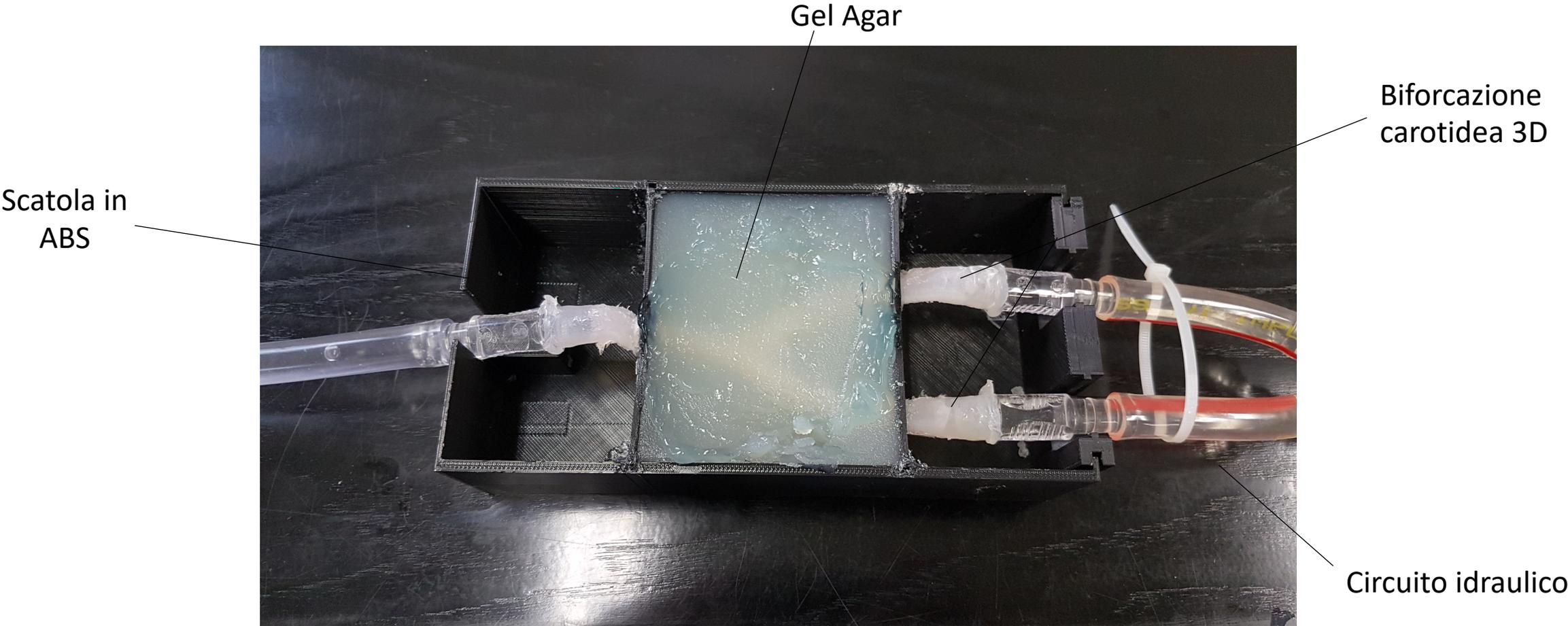


# Modello di biforcazione



Modello in vitro

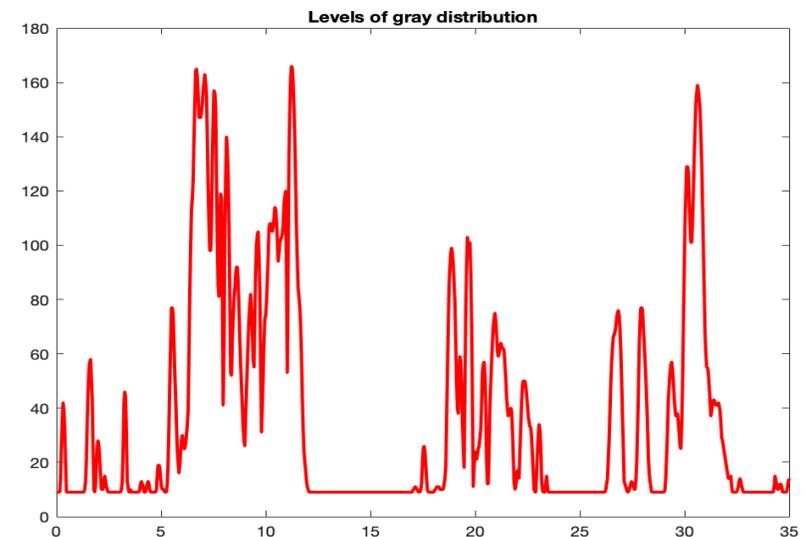
# Modello di biforcazione



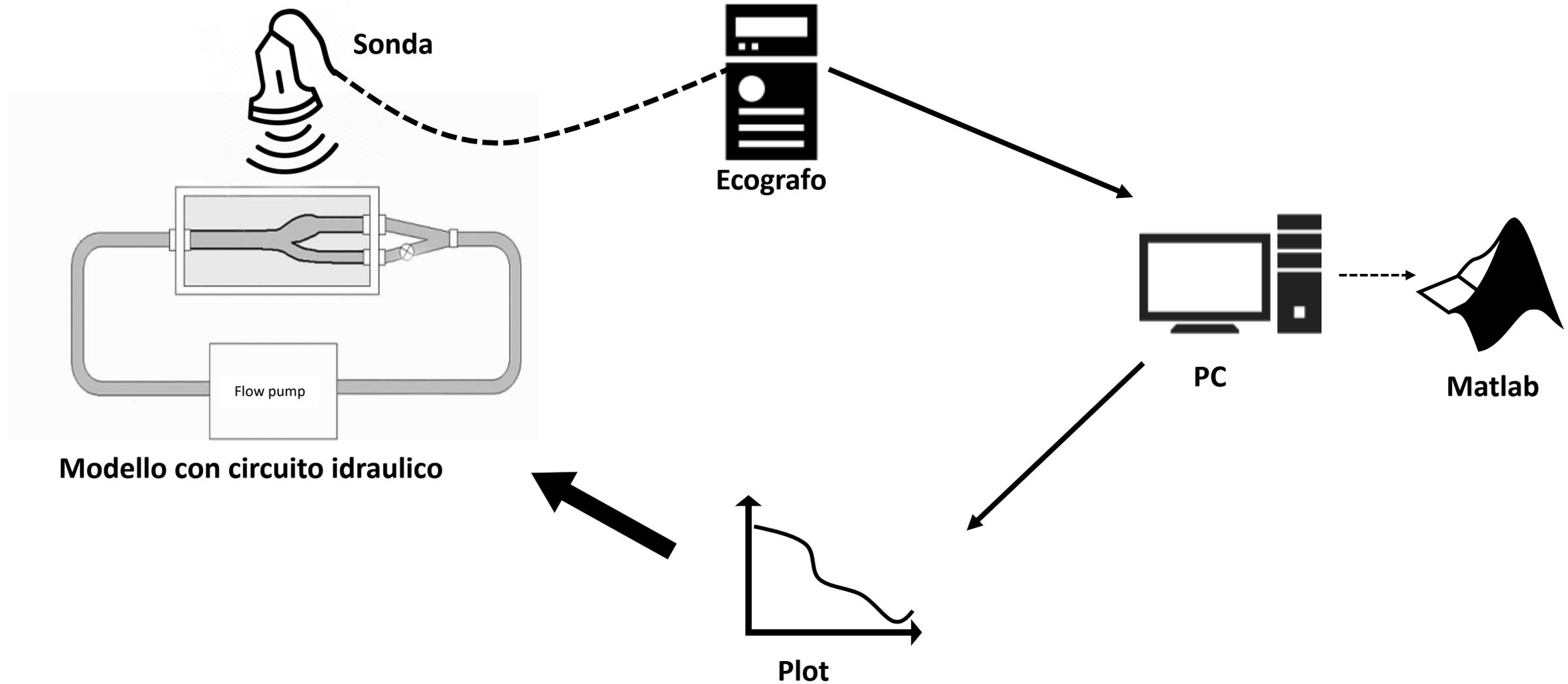
**Modello in vitro**

# Obiettivi

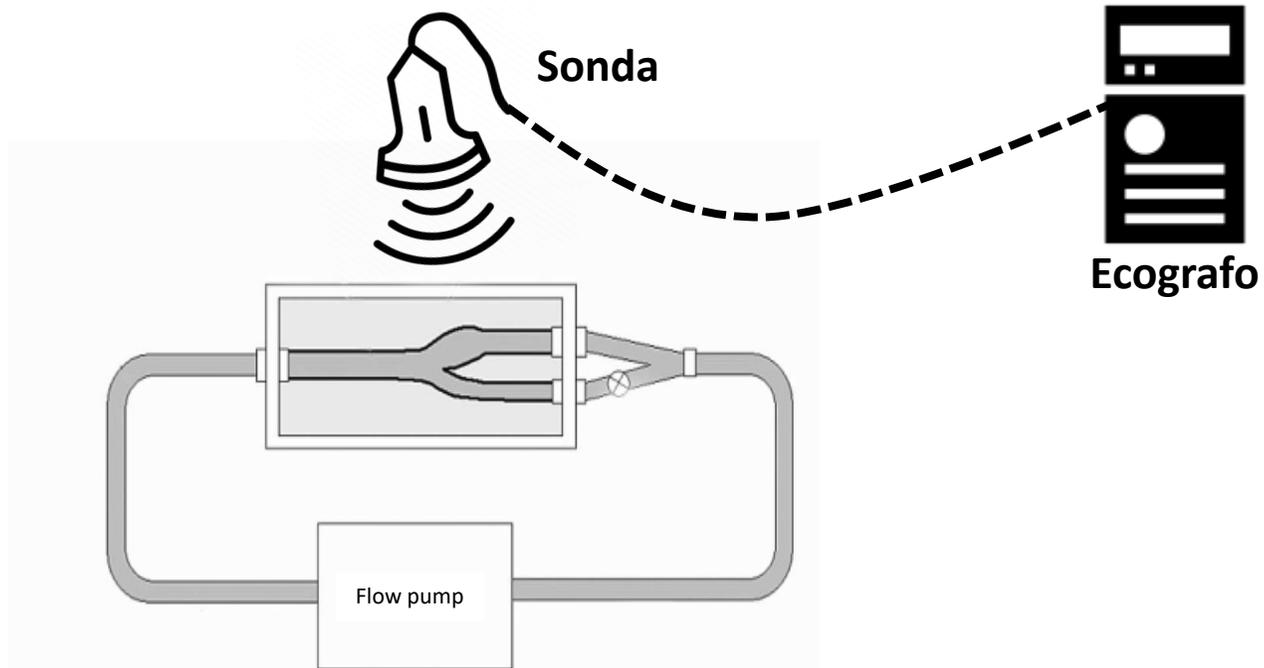
- Quantificare **ecogenicità** del modello phantom con **ecografo non-clinico**
- Individuare i parametri ottimali per raggiungere gli **standard clinici** per l'uso del modello di biforcazione



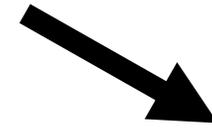
# Framework lavoro



# Framework lavoro



**Modello con circuito idraulico**



**ULA-OP 64**

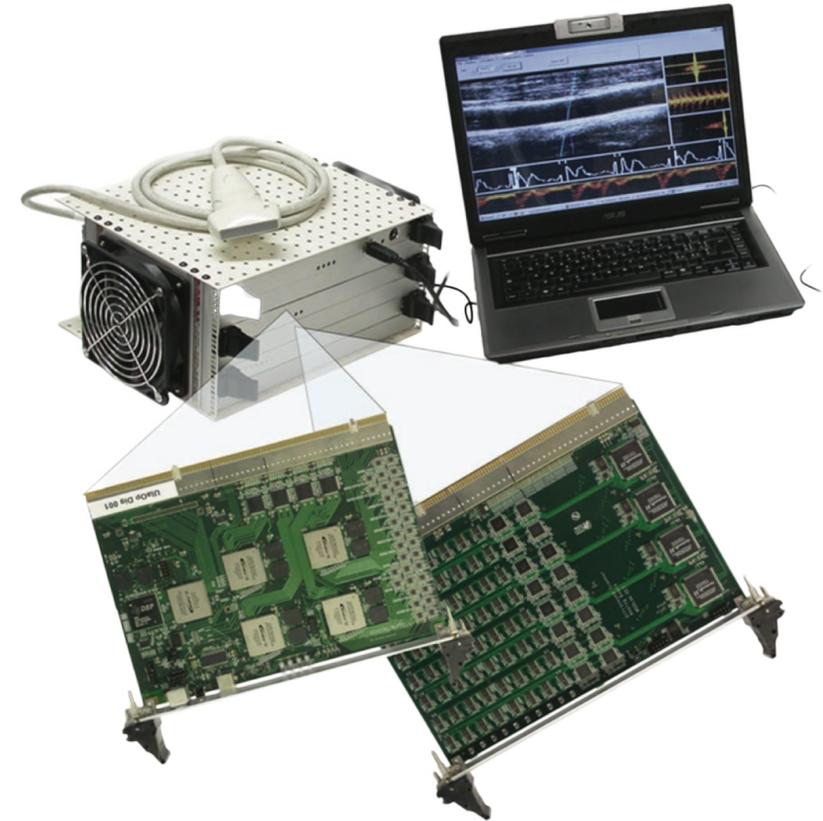
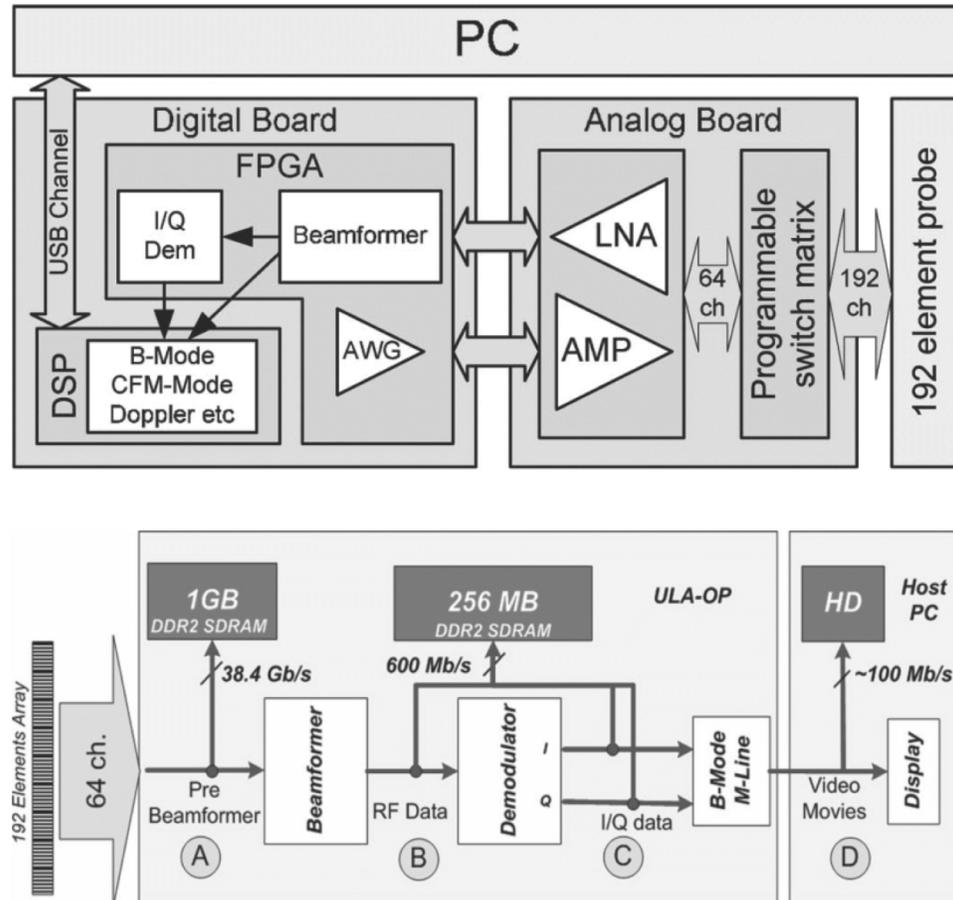
# Ultrasound Advanced Open Platform

---

- Piattaforma ecografica a 64 canali TX/RX
- Elaborazione grafica in tempo reale
- Possibilità di gestire dati grezzi
- Software PC con *pre e post processing tools*
  - *B-Mode, M-Mode, Multi-Gate Spectral Doppler*



# Specifiche di ULA-OP 64



1. P. Tortoli, L. Bassi, E. Boni, A. Dallai, F. Guidi and S. Ricci, **ULA-OP: an Advanced Open Platform for Ultrasound Research**, IEEE Trans. Ultrason., Ferroelect., Freq. Contr, 2009. DOI: 10.1109/TUFFC.2009.1303
2. Boni, Bassi, Dallai, Guidi, Ramalli, Ricci, Housden, and Tortoli, **A Reconfigurable and Programmable FPGA based System for non-standard Ultrasound Methods**, IEEE Trans. on Ultrason. Ferroel and Freq. Control, 2012. DOI: 10.1109/TUFFC.2012.2338
3. Tortoli, V.Michelassi, G.Bambi, Guidi, D.Righi, **Interaction between secondary velocities, flow pulsation and vessel morphology in the common carotid artery**, *Ultras Med Biol*, vol 29 n.3, pp.407-415, 2003.

# Esaote LA533

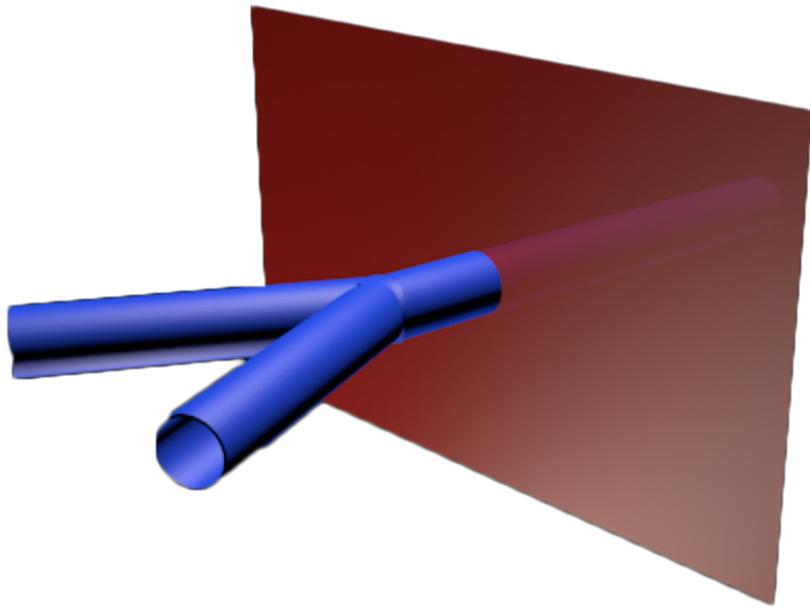
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- Sonda ecografica lineare
- Prodotta dall'azienda genovese Esaote
- Array lineare da 192 elementi
- Indicata per *imaging* vascolare e di piccole parti

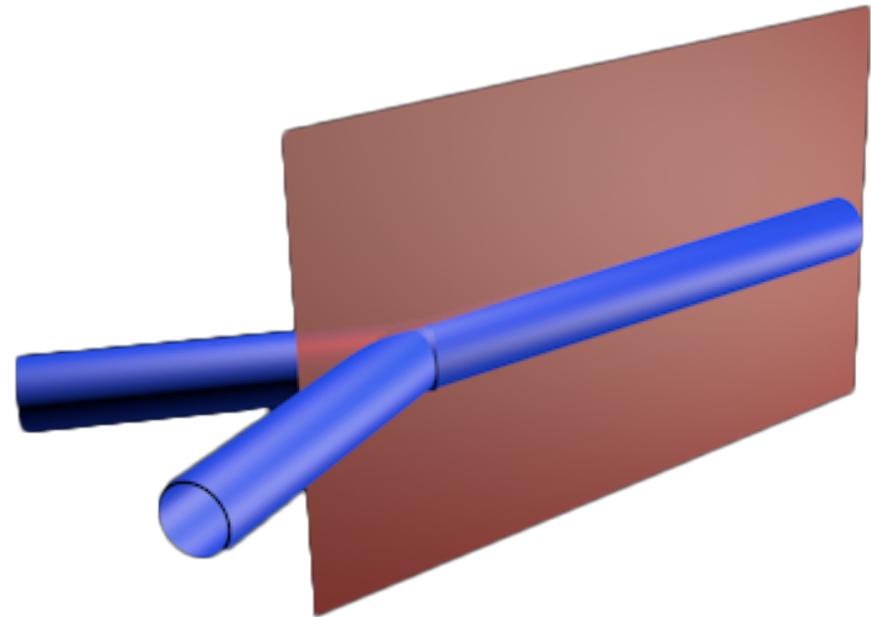


# Esate LA533

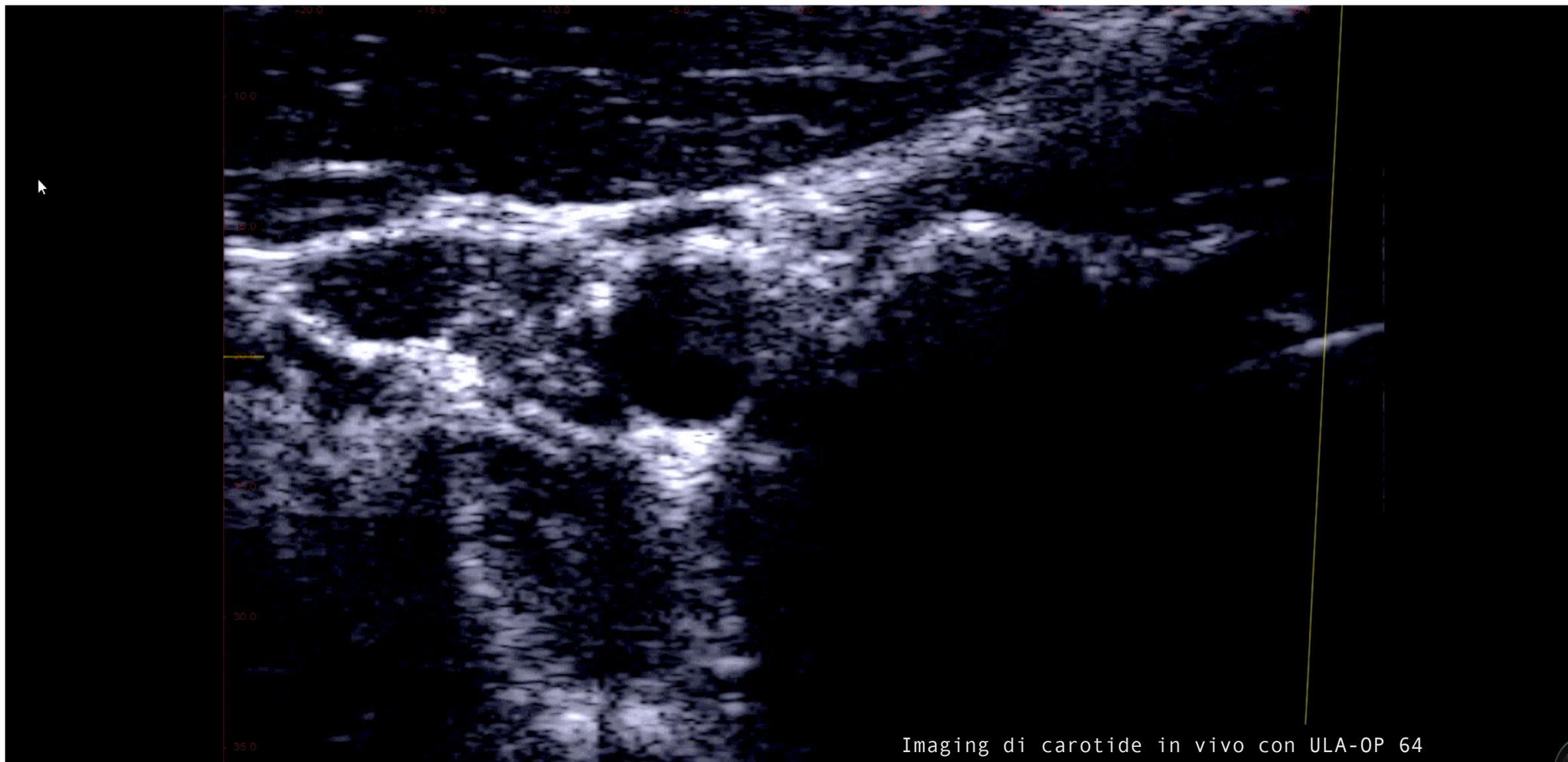
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Vista trasversale

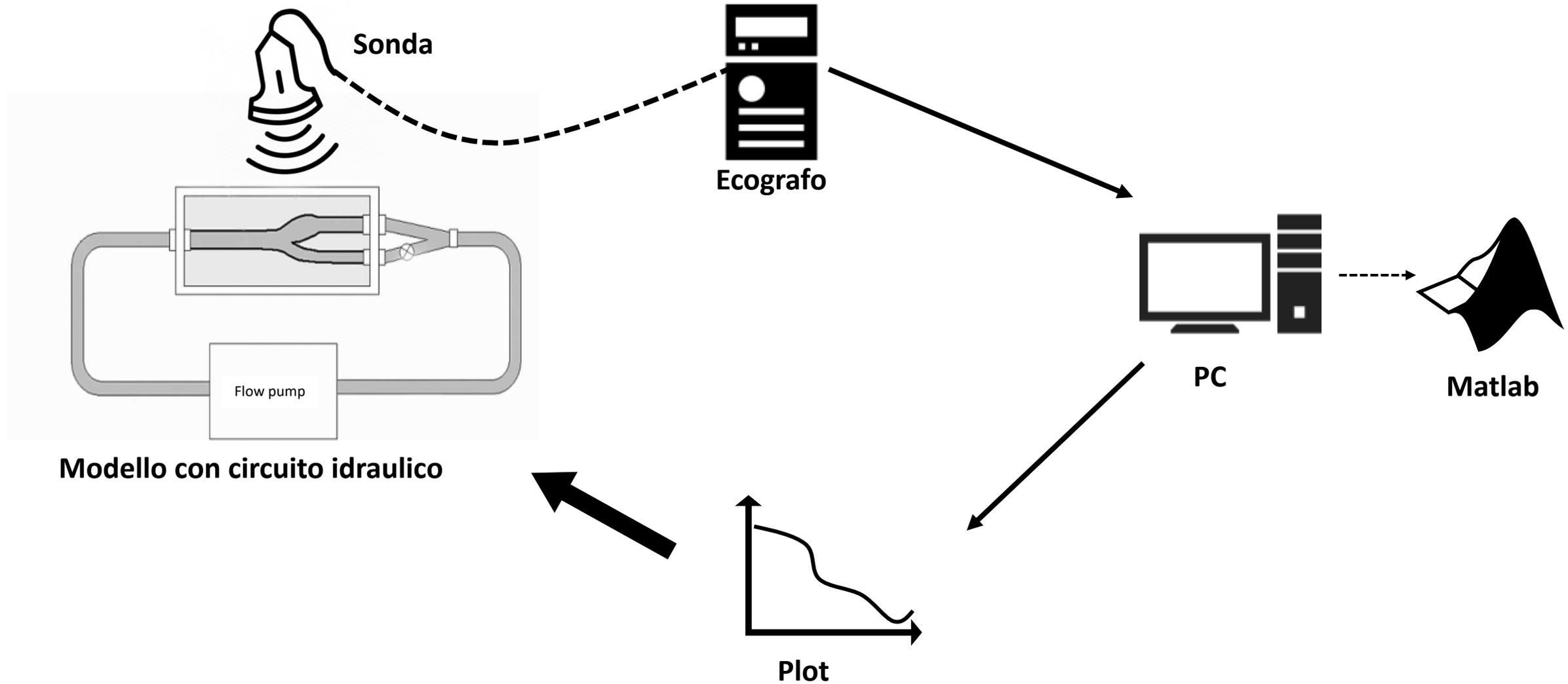


Vista longitudinale

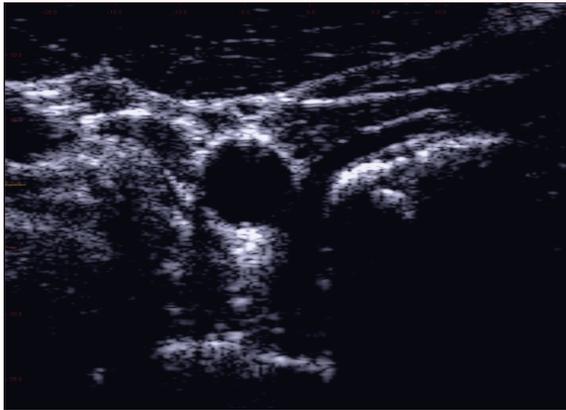


Imaging di carotide in vivo con ULA-OP 64

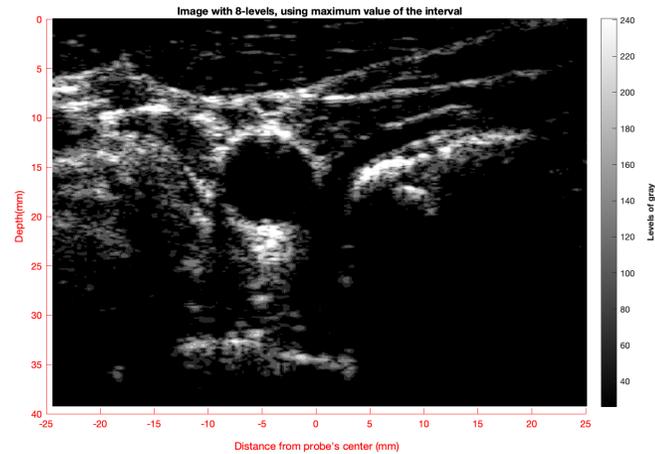
# Framework lavoro



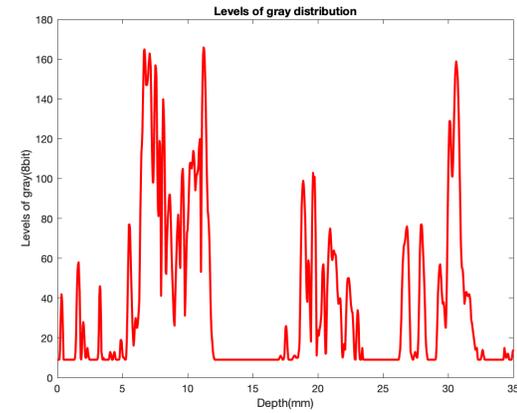
# Framework lavoro



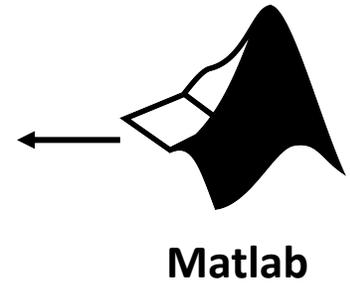
Raw image



Grayscale



Plot



Matlab

# Metodo di acquisizione

## ➤ Ecografia in B-Mode

- Ogni eco viene presentata come un punto luminoso la cui tonalità di grigio è proporzionale all'intensità dell'eco.

## ➤ Combinazioni di 4 parametri

### ➤ Post-acquisizione

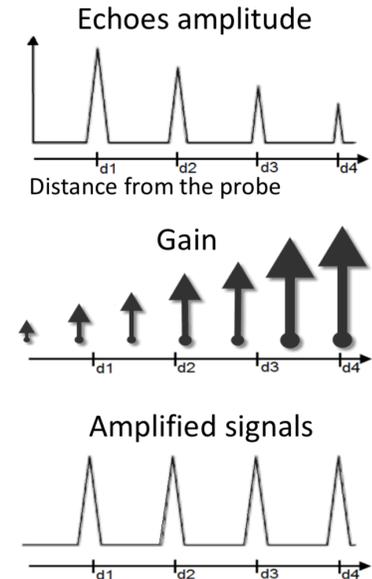
#### ➤ Time Gain Compensation

- TGC A
- TGC B

### ➤ Imaging

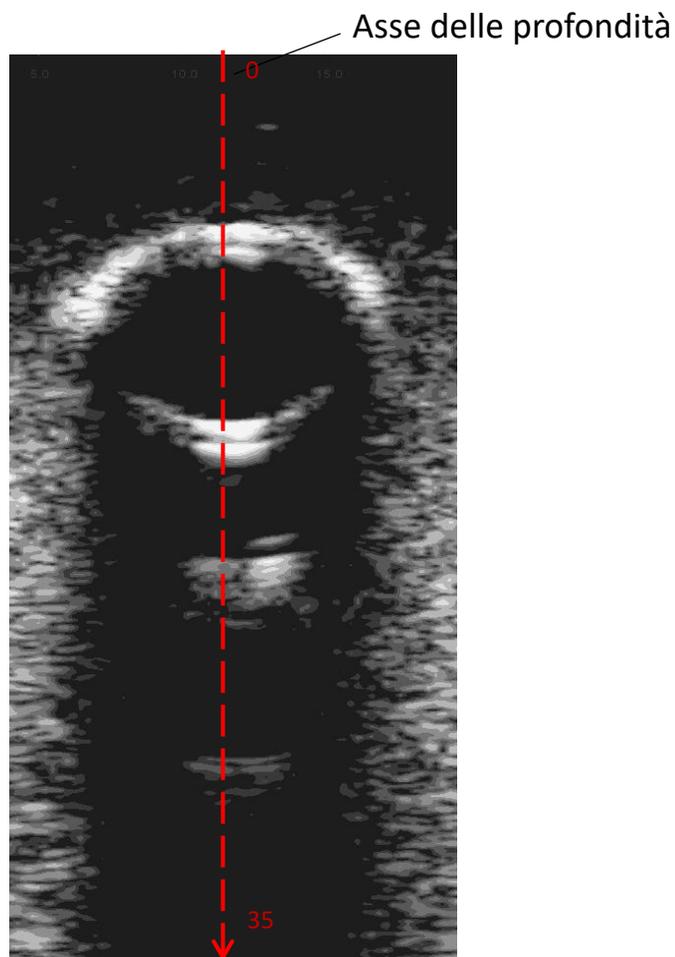
- Threshold
- Dynamic

Scelta di parametri dinamici modificabili senza intervenire su codice

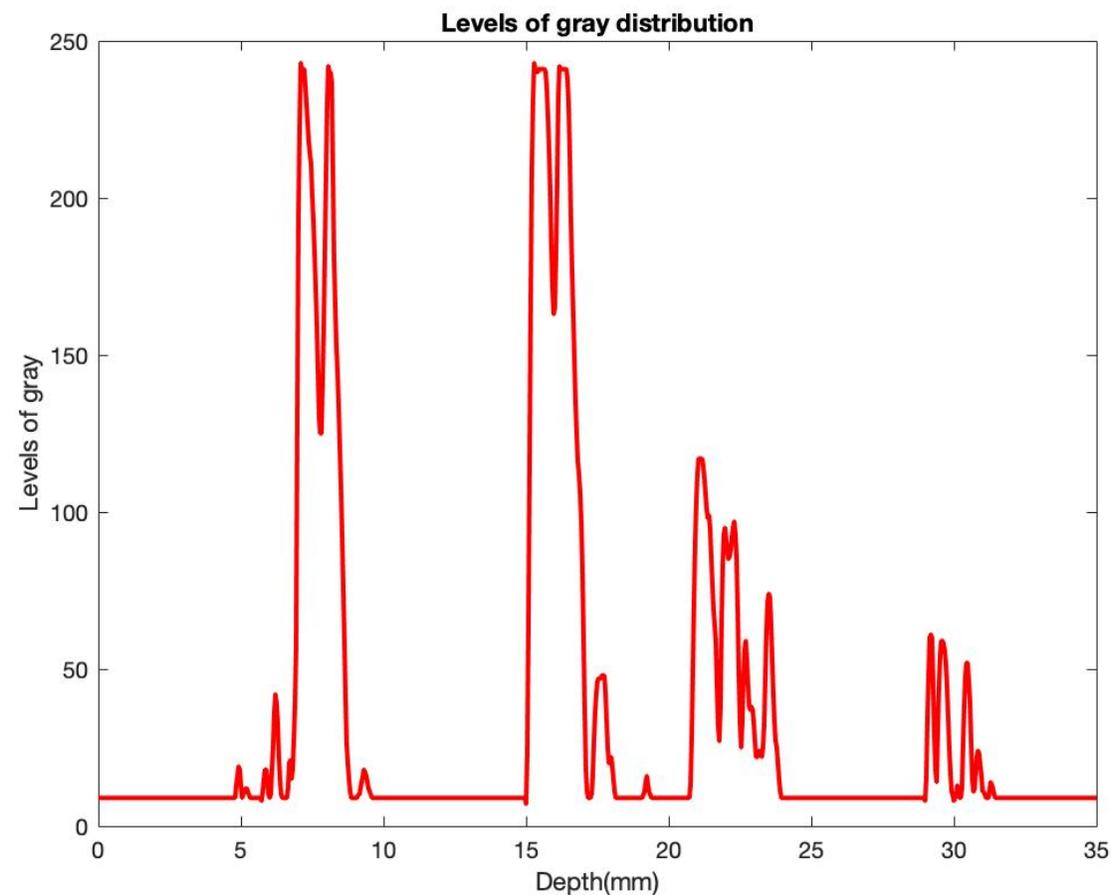


- Tx Frequency
- Ty Focus
- Tx Nc
- Tx Amp
- Tx Window
- Tx Apodization
- Rx Focus type

# Matlab



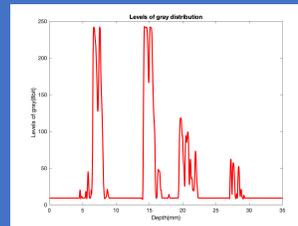
**Immagine convertita in scala di grigi  
(vista frontale)**



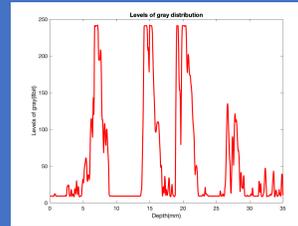
**Livelli di grigio lungo l'asse selezionato**

# Risultati

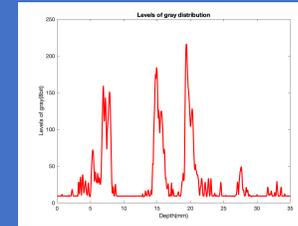
A  
Threshold 11  
Contrast 10



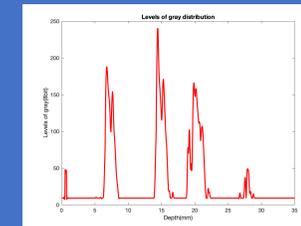
B  
Threshold 8  
Contrast 10



C  
Threshold 8  
Contrast 13



D  
Threshold 11  
Contrast 13

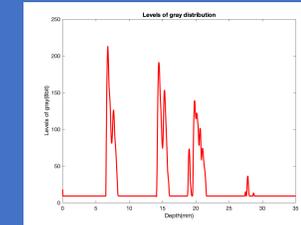
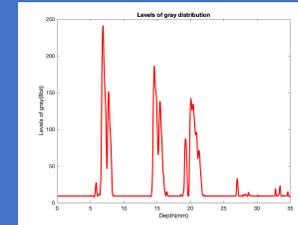
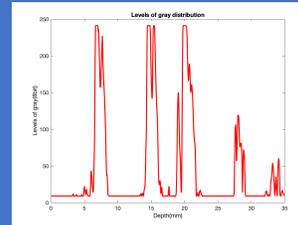
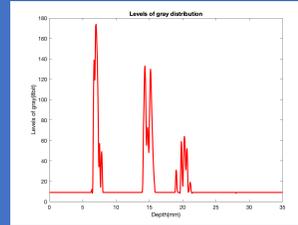
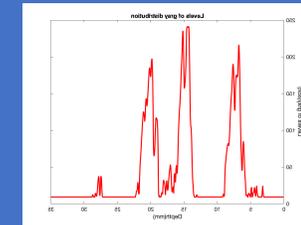
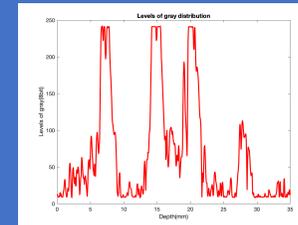
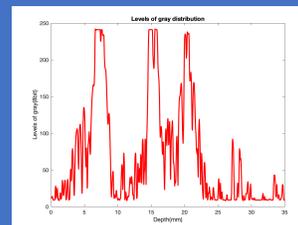
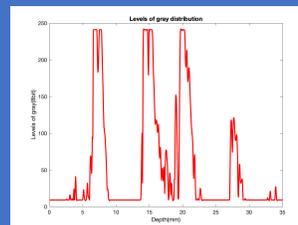
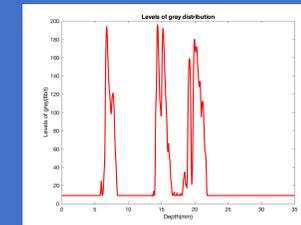
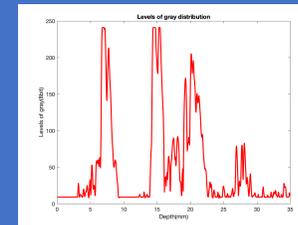
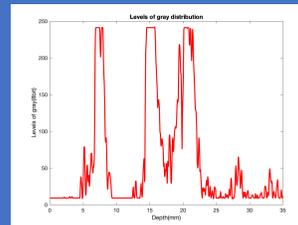
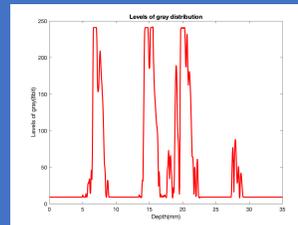


I  
TGC A 18  
TGC B 10.3

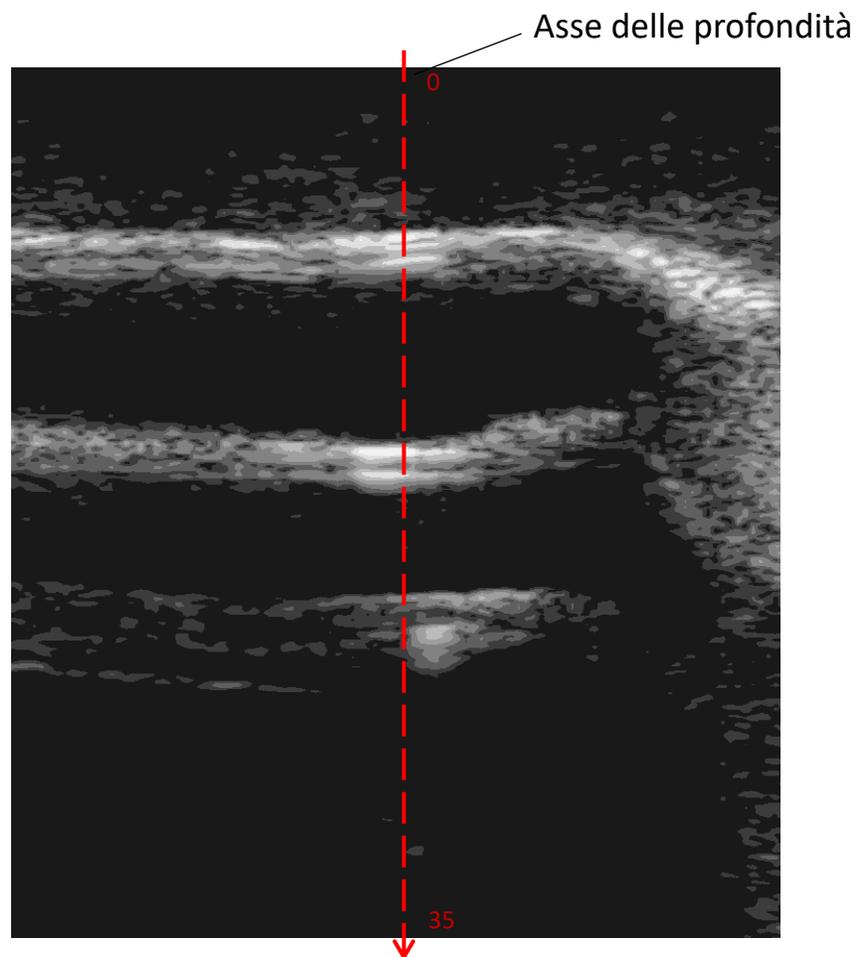
II  
TGC A 10  
TGC B 17.6

III  
TGC A 18  
TGC B 16.2

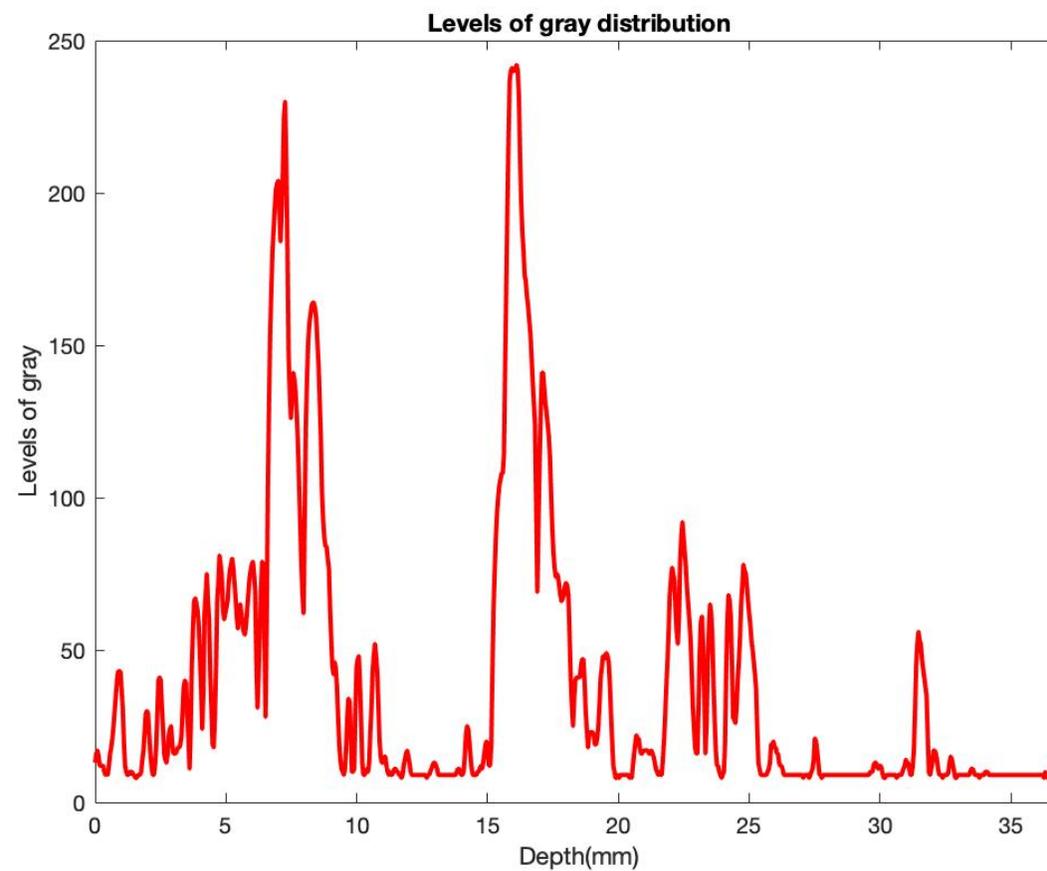
IV  
TGC A 10  
TGC B 10.3



# Matlab



**Immagine convertita in scala di grigi  
(vista longitudinale)**



**Livelli di grigio lungo l'asse selezionato**

## ➤ Rilevazioni su modello in-vitro

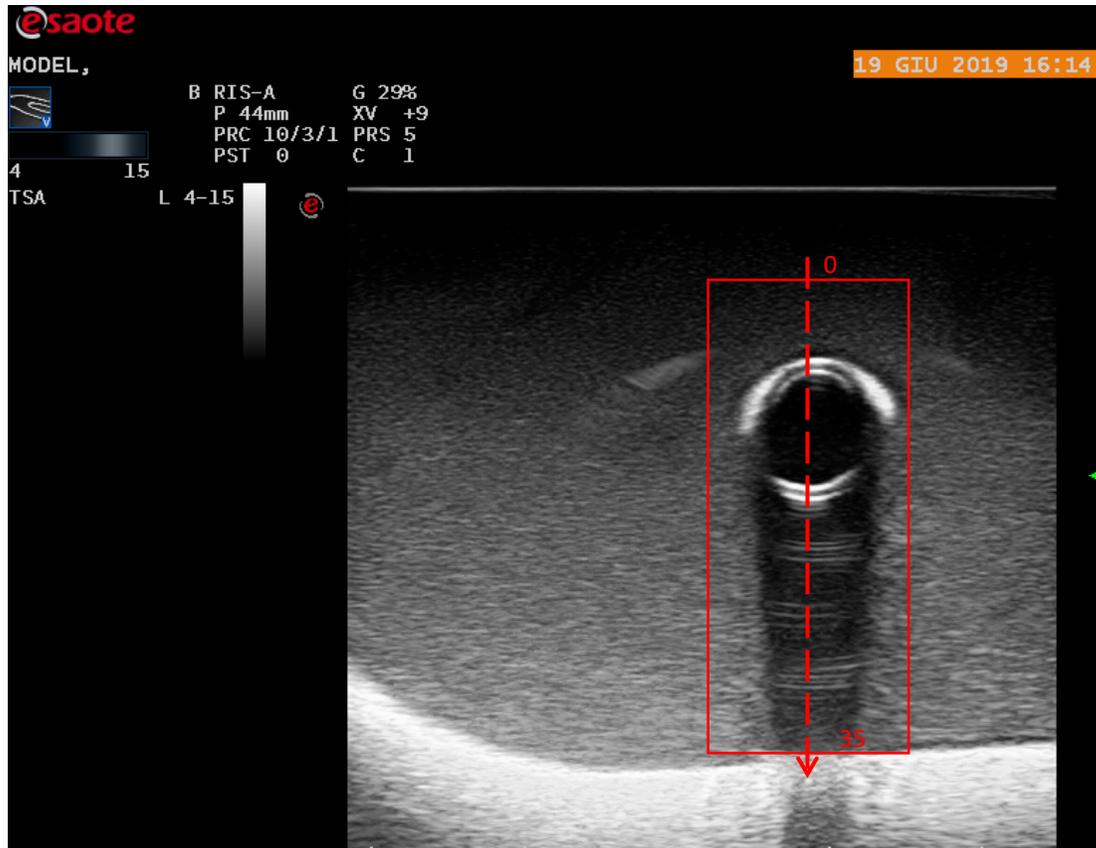
### ➤ Ecografo clinico

- Filtri digitali per rimuovere grana
- Ridotta presenza cono d'ombra: più marcato su trasversale, meno su longitudinale

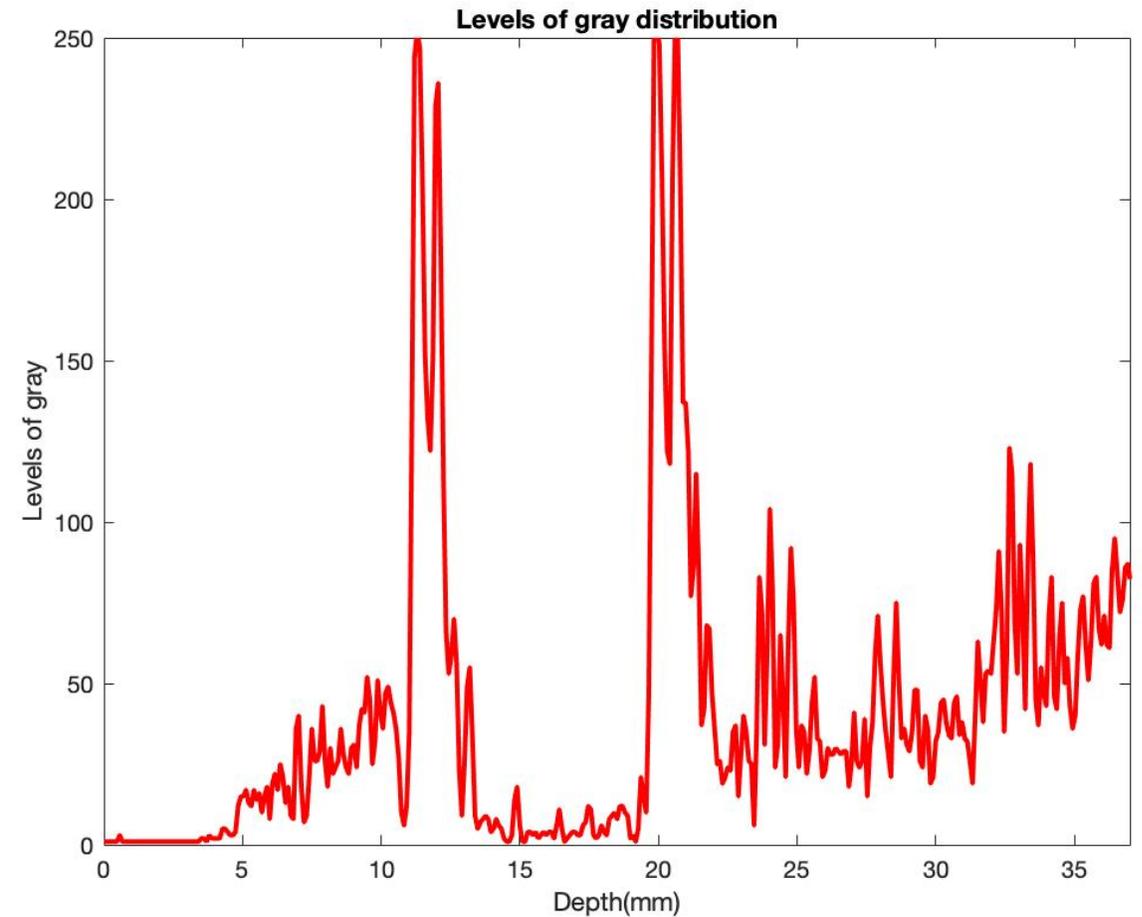
## ➤ Esperienza su pazienti

- Elastografia
- Quantitative Ultrasound (QUS)
- Echo 3D

# Analisi su immagini cliniche

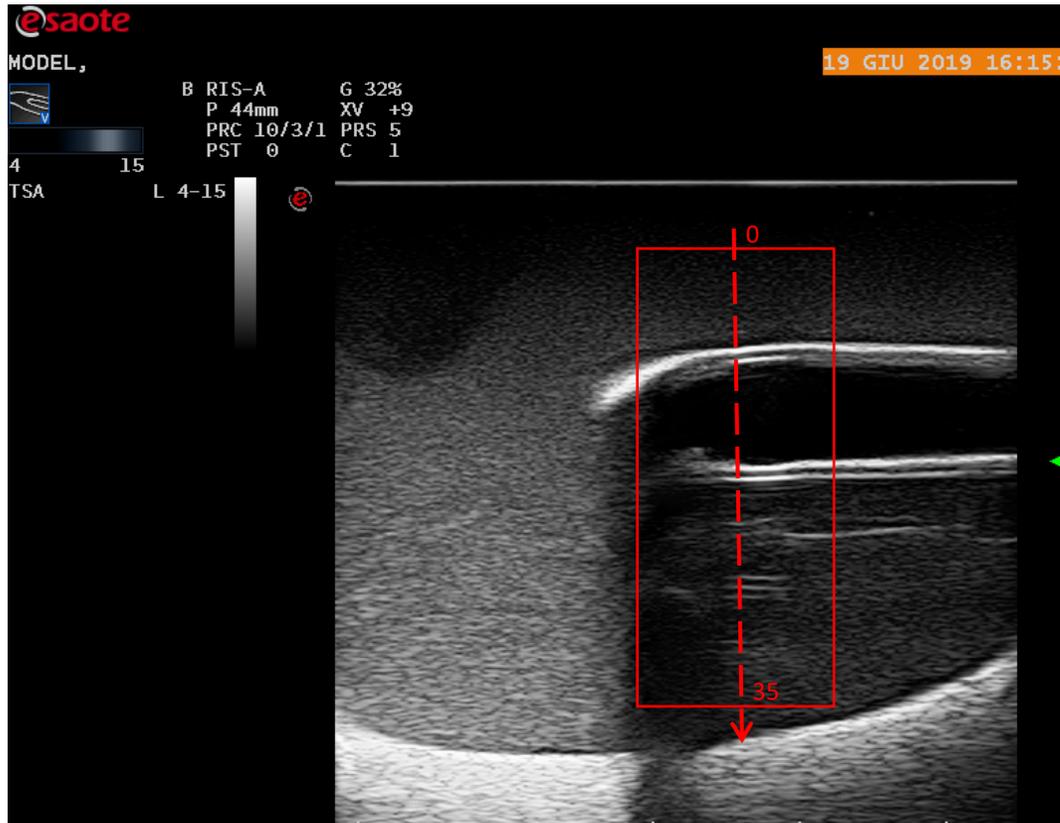


Sezione trasversale

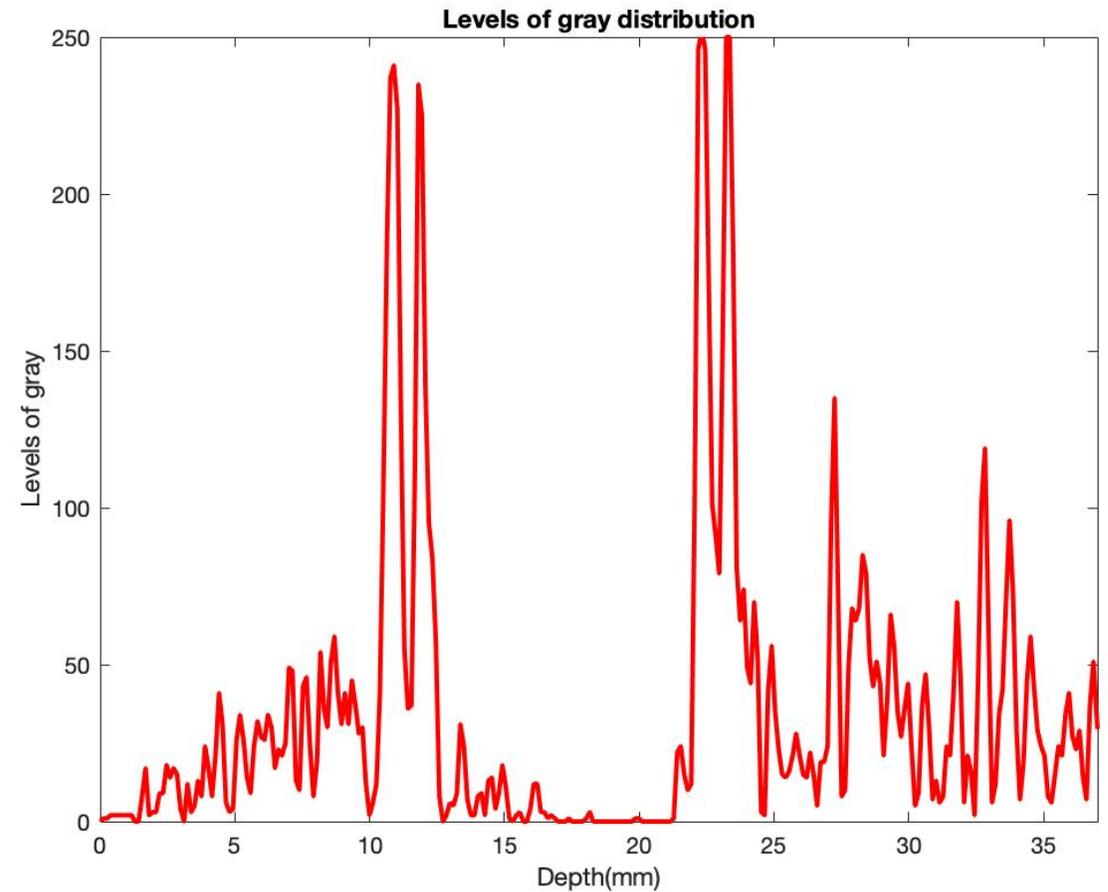


Livelli di grigio lungo l'asse selezionato

# Analisi su immagini cliniche



Sezione longitudinale



Livelli di grigio lungo l'asse selezionato

# Confronto dei risultati

A  
Threshold 11  
Dynamic 10

B  
Threshold 8  
Dynamic 10

C  
Threshold 8  
Dynamic 13

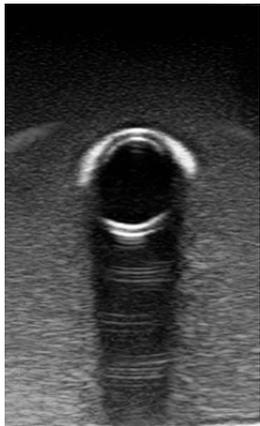
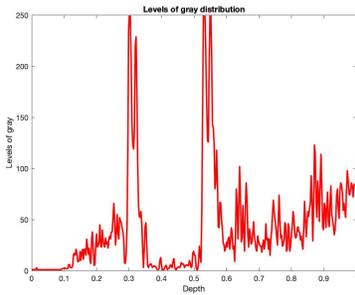
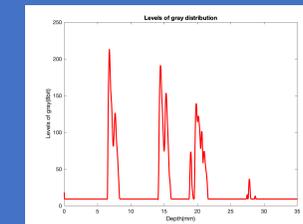
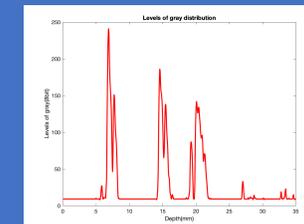
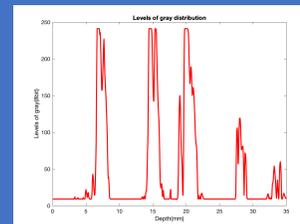
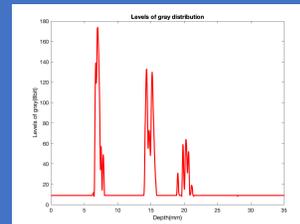
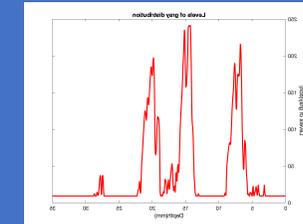
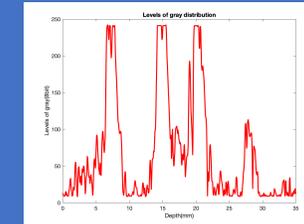
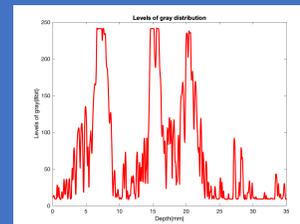
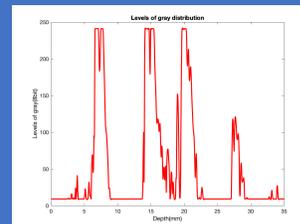
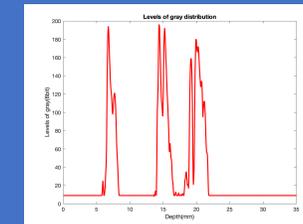
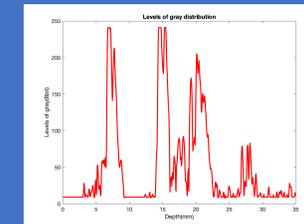
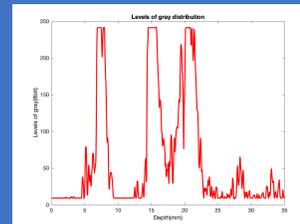
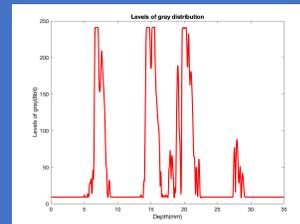
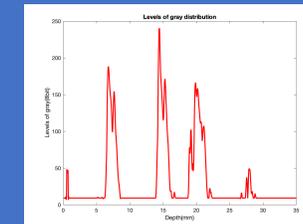
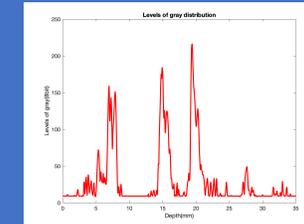
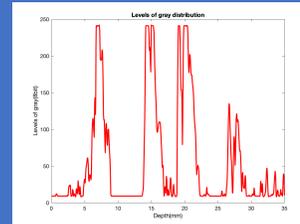
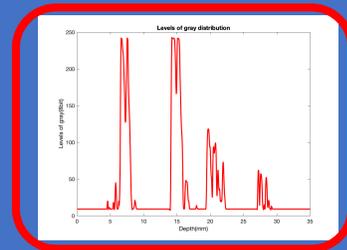
D  
Threshold 11  
Dynamic 13

I  
TGC A 18  
TGC B 10.3

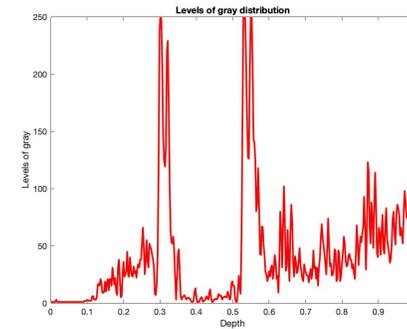
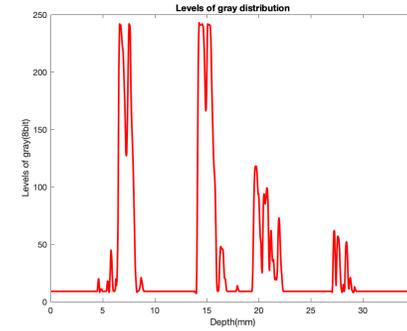
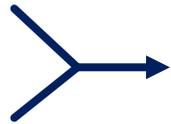
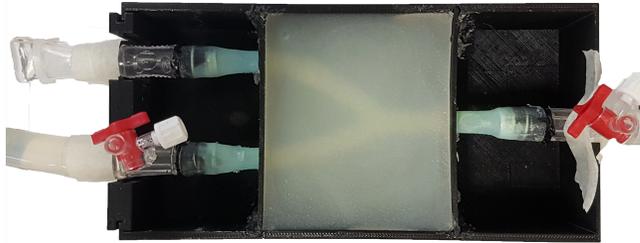
II  
TGC A 10  
TGC B 17.6

III  
TGC A 18  
TGC B 16.2

IV  
TGC A 10  
TGC B 10.3



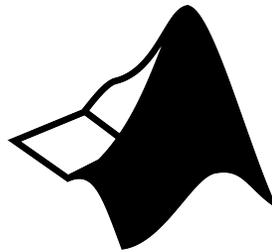
# Conclusioni



- TGC A **18**
- TGC B **10.3**
- Threshold **11**
- Contrast **10**



**Fase 1**  
Acquisizione



**Fase 2**  
Elaborazione

**Fase 3**  
Grafici

**Fase 4**  
Confronto e scelta

# Problematiche

---

- Acquisizioni operatore – dipendenti
- Presenza di artefatti (cono d'ombra, riverberi)
- Compatibilità dati grezzi con software Matlab
- Alto numero di gradi di libertà
- Bontà immagine non univocamente quantificabile



# Sviluppi futuri

---

- Limitare dipendenza da operatore (ridurre «errore umano»)
- Esperimenti con flusso pulsatile (sviluppo SW/HW)
- Sviluppo di phantom con geometrie più complesse (inspessimenti, malformazioni ecc.)



Facoltà di Ingegneria  
Dipartimento di Ingegneria Civile e Architettura (DICAr)

**GRAZIE PER L'ATTENZIONE!**

candidato: **Armando Oscar Rossi**  
relatore: **prof. Michele Conti**  
correlatore: **dott.ssa Giulia Matrone**



# Problematiche

---

- Elastografia
  - risultati paziente e operatore-dipendenti
- QUS
  - errori nel tracking delle pareti in presenza di placche
  - Necessaria B-Mode per individuazione sito placca
- Echo 3D
  - Segmentazione manuale dei piani 2D
  - Procedura onerosa (numero di piani > 20)
  - Operatore-dipendente

- **Agilus30 Pro** - *fotopolimero PolyJet caratterizzato da resistenza a strappo, flessione e piegature ripetute*
  - Resistenza trazione 2.4 – 3.1 Mpa
  - Allungamento a rottura 220 – 270 %
  - Resistenza a strappo 5 – 7 kg/cm
  - Durezza A 30 Shore
  
- **VeroCiano** - *fotopolimero policromatico multifunzione*
  - Resistenza trazione 60 – 70 Mpa
  - Resistenza flessione 75 – 110 Mpa
  - Tenacità intaglio 20 – 30 J/m
  
- **TangoPlus** - *materiale dalla flessibilità simile a quella della gomma, simula gli elastomeri termoplastici*
  - Resistenza trazione 0.8 – 1.5 Mpa
  - Allungamento a rottura 170 – 220%
  - Resistenza a strappo 2- 4 kg/cm
  - Durezza A 26 – 28 Shore