Università degli Studi di Pavia

Dipartimento di Ingegneria Civile e Architettura

Corso di Laurea in Bioingegneria

3D Printing per la pianificazione del trattamento endovascolare dell' auricola atriale sinistra

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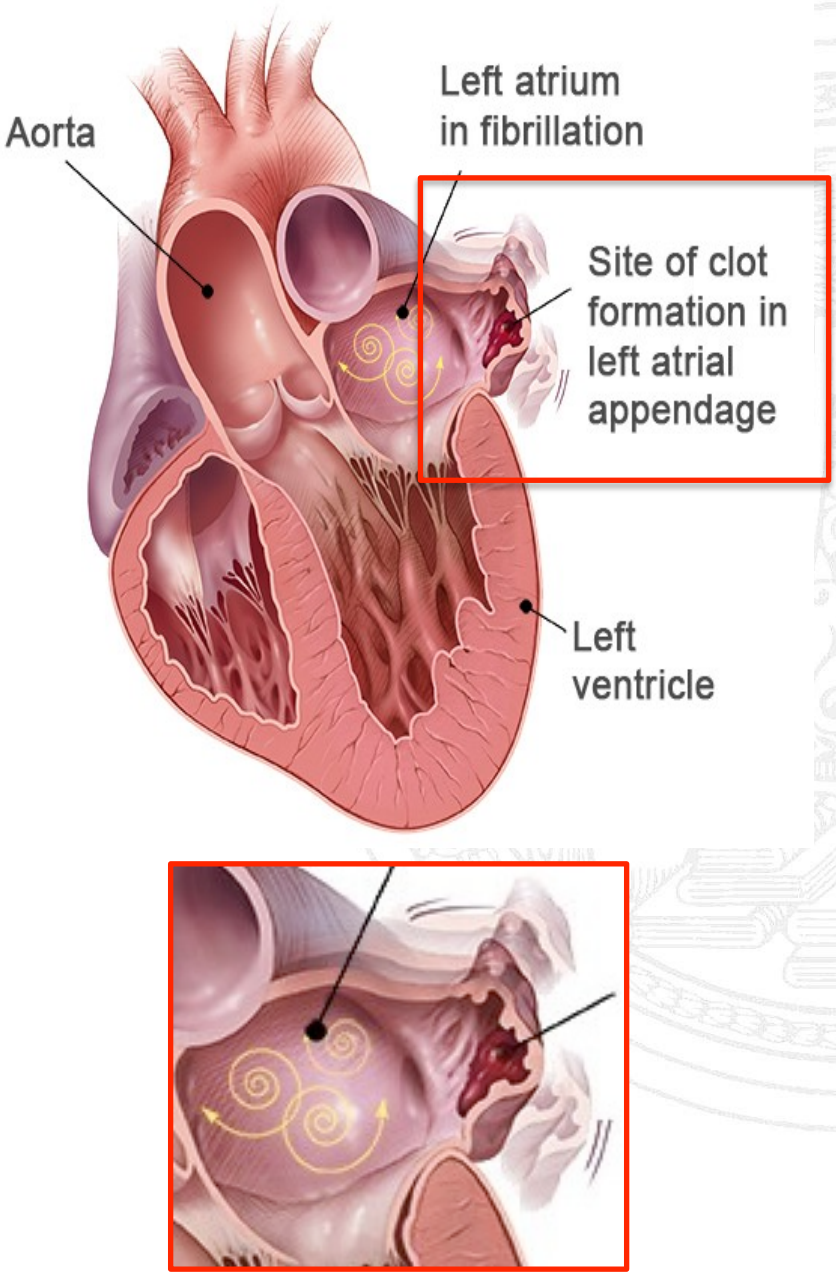
Relatore: **Prof. F. Auricchio**

Ringraziamenti: **Dott. M. Conti**

Anno Accademico: 2014/2015

Clinical Problem: Ischemic Stroke



Atrial Fibrillation

↓

Clots formation into LAA

↓

Carried by bloodstream towards brain

↓

Occlusion of brain vessels

↓

RISK

↓

Ischemic stroke

LAA Treatment

Pharmacological Treatment

Anticoagulant Oral Therapy
TAO

↓

Warfarin

Disadvantages:
- Strict control of therapeutic range
- Risk of haemorrhage

Endovascular Treatment

↑ Choice for non suitable TAO people

LAA Endovascular Treatment

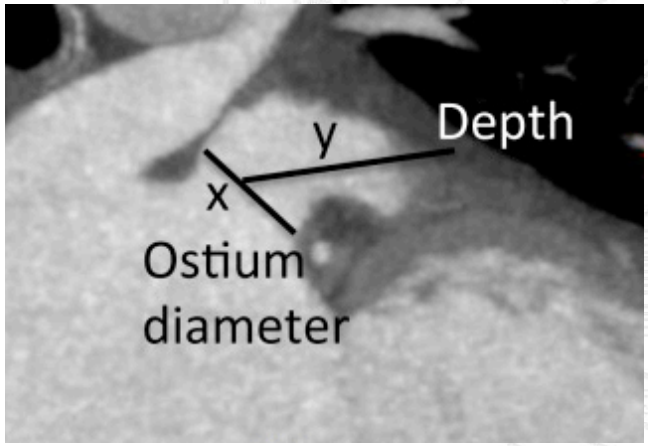
Pre Endovascular Treatment

WITH

AMPLATZER™ Amulet™LAA Occluder

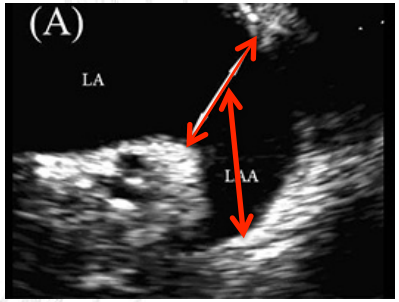
Post Endovascular Treatment

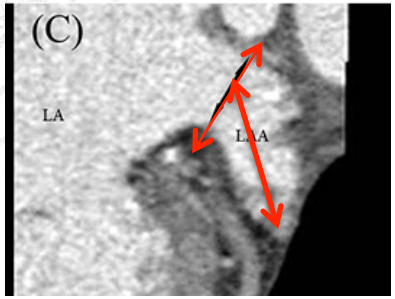
Measurement



Taken with

- **TEE**
- **MDCT**





3D PRINTING → **Patient's specific model**

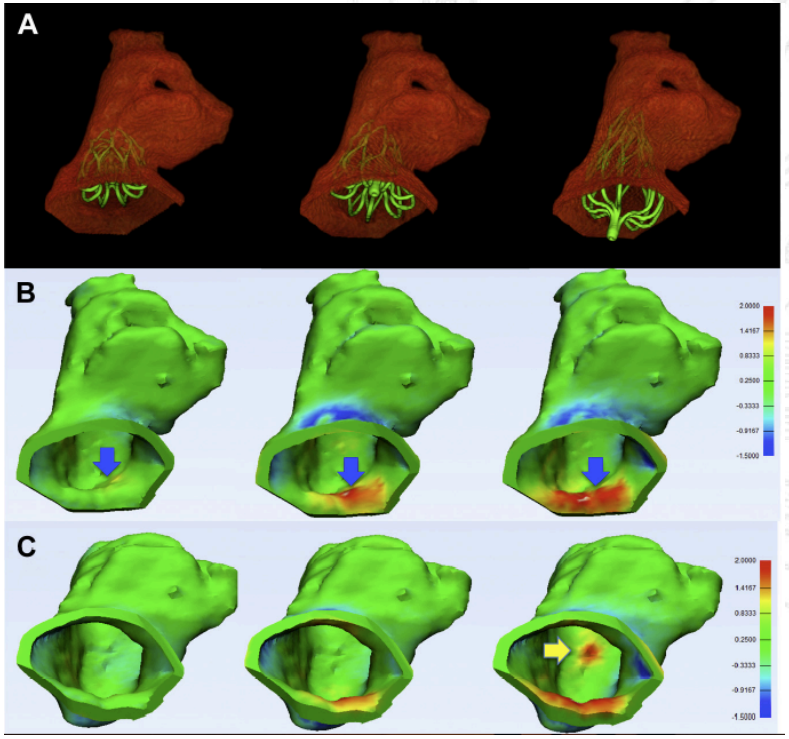
3D Printing – A Study Case from Literature

Medical Case: 74-year old man, ischemic cardiomyopathy, intolerance of anticoagulation

Procedural plan: Pre-procedural imaging and employment of 3D printing

Imaging → TEE and MDCT → Measurement → Optimal device : 21 mm

3D Printed model → Segmentation → STL → 3D printing → 3D rubber-llike LAA model



Placement of different sized devices (21mm, 24mm, 27mm)

Simulation of atrial mechanical properties

Re imaging with CT

Calculus of anatomical deformation

} Optimal device : 24 mm

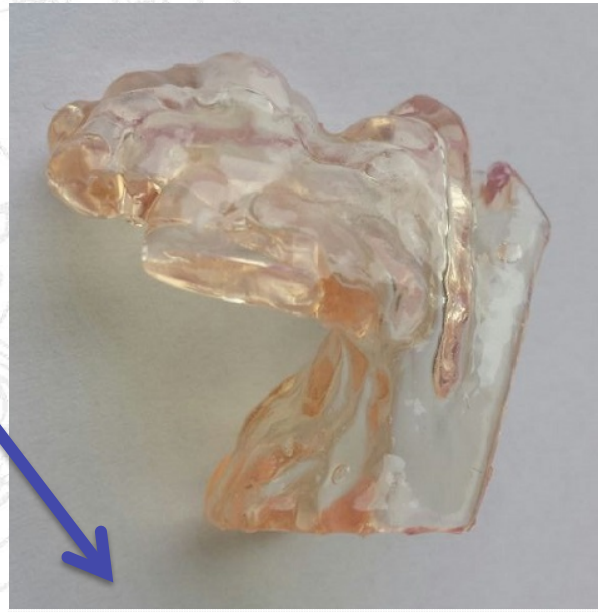
Result : 3D printing allows the choice of the optimal device and avoids device embolization

Source: Left Atrial Appendage Closure Guided by Personalized 3D-Printed Cardiac Reconstruction

Goal

Centro Cardiologico Monzino

?



CareTronik

solutions for life

Goal (cont.)

Centro Cardiologico Monzino

Patient already treated → CTA pre surgical intervention (Monzino) → Segmentation Processing (Unipv) → 3D printing → Device test demo (Monzino) → Comparison with reality

CTA pre surgical intervention (Monzino) → CTA

Segmentation Processing (Unipv) → STL

Comparison with reality → Measurement decision

Comparison with reality → Does it match?

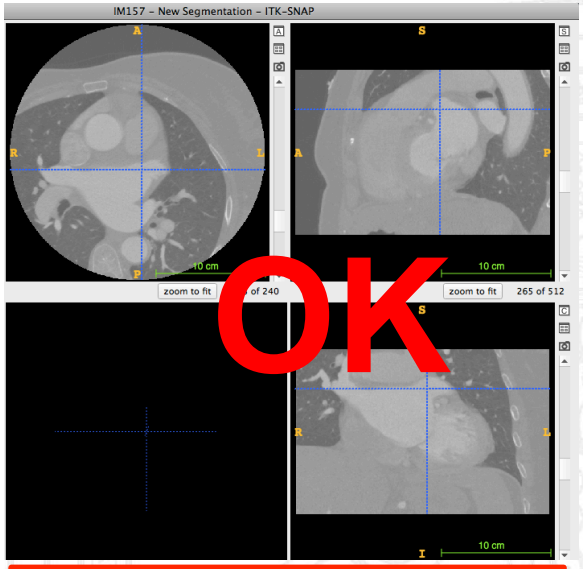
Does it match?

- Match no problem — OK
- Match with problem — Adverse case
- Not matching no problem — Adverse case
- Not matching with problem — **OPTIMAL CASE Evaluate if printing support can fix the problem**

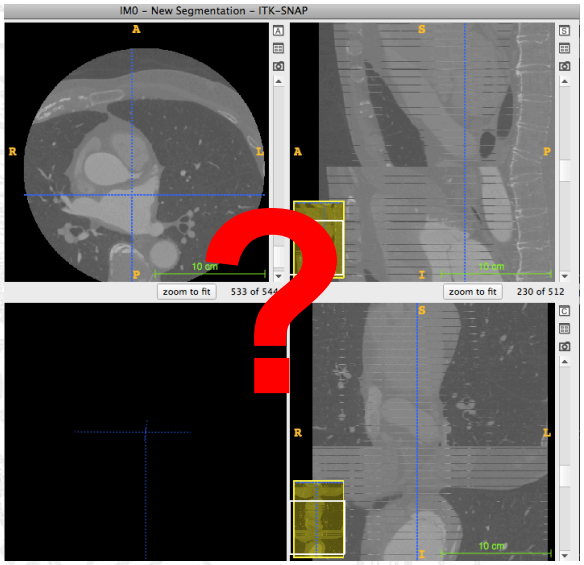
CareTronik solutions for life

Segmentation Flow

Visual Analysis

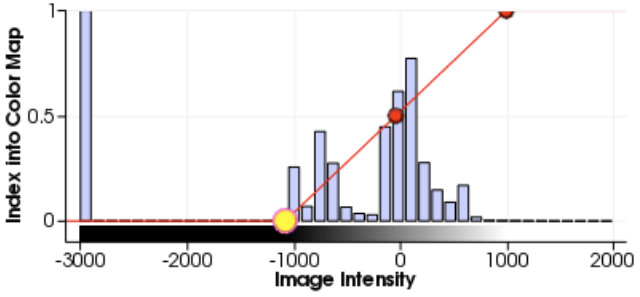


Good Quality *N good = 11*

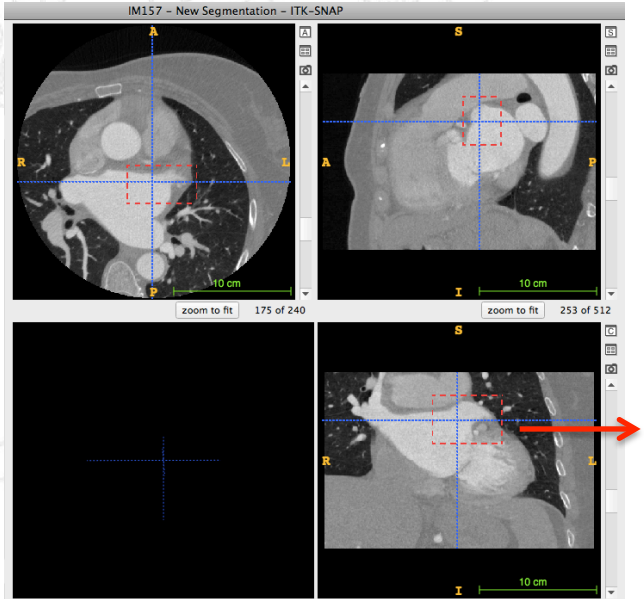


Bad Quality *N bad = 10*

Contrast Adjustment



highlight LAA by
changing red line shape

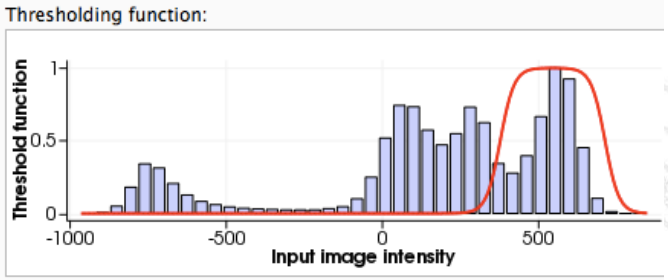


Selection of
ROI

Segmentation Flow (cont.)

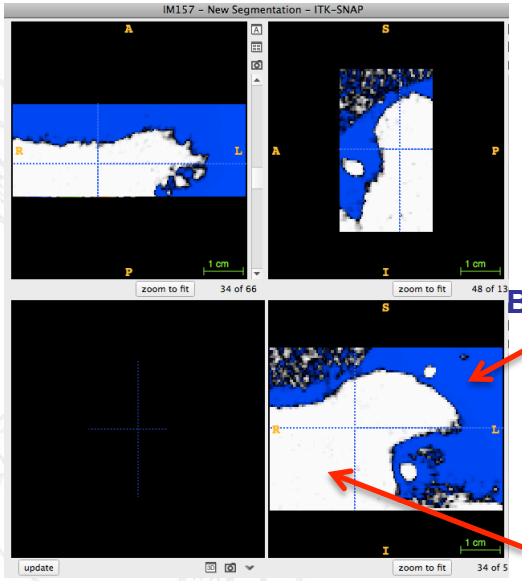
Thresholding

Distinction between background and foreground region (Object of interest)



Lower and Upper threshold adjustment applying Band Pass Filter

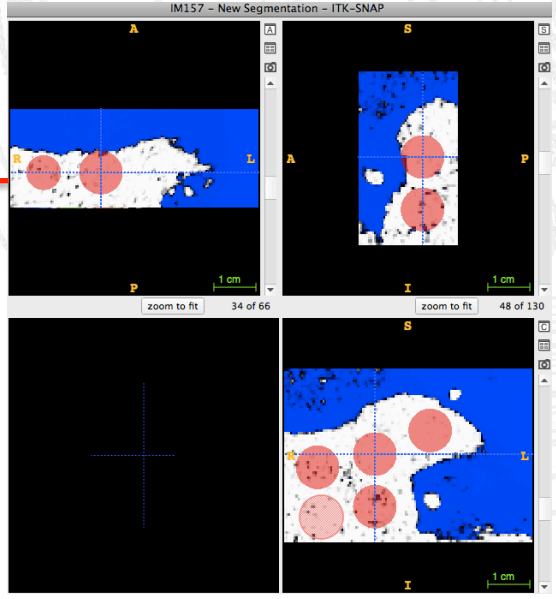
Intensitiy
- Background = -1
- Borderline = 0
- Foreground = +1



Automatic Segmentation

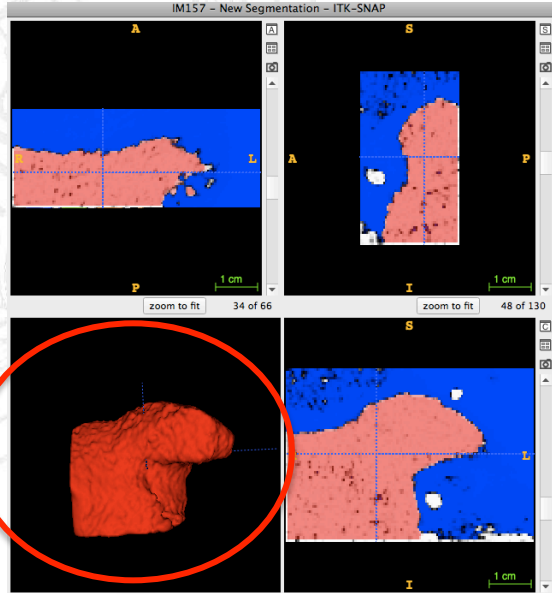
Region Competition

snake initialisation with ***bubbles***



Increase where intensity = +1

Decrease where intensity = -1



Output of segmentation is a .STL file

Segmentation flow: Noisy Images

If bad quality is due to noise ? → **Pre-Processing**

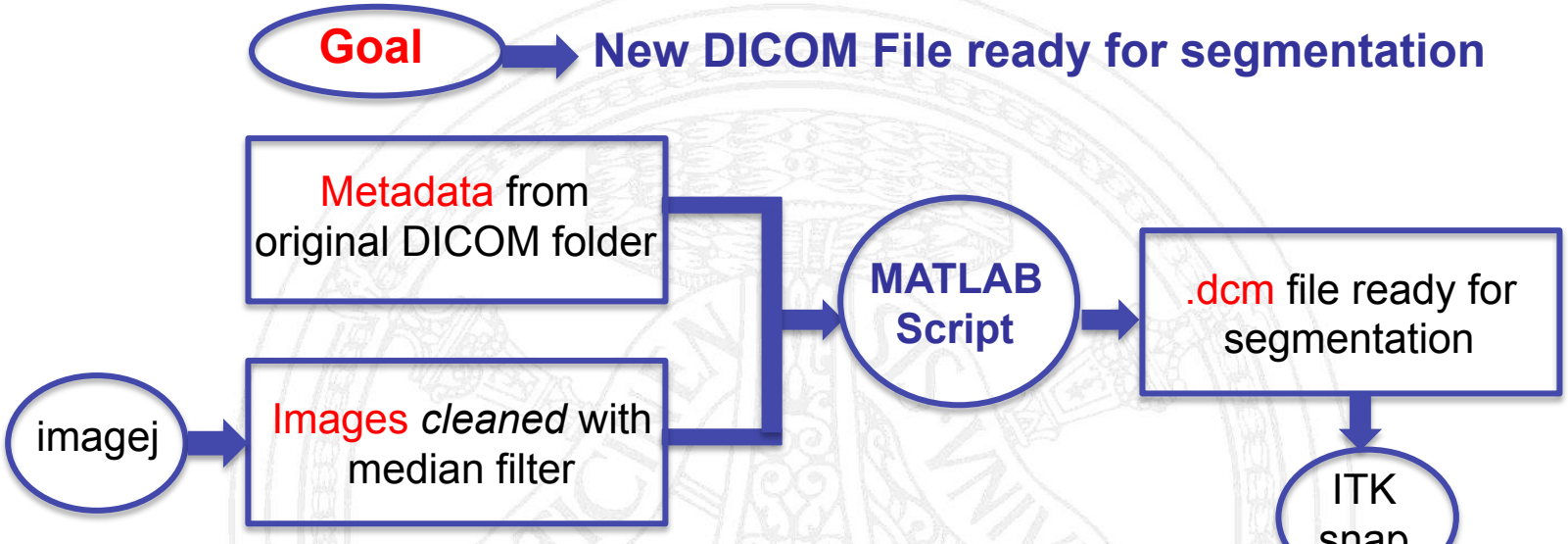
N bad= 7 → N noise = 3

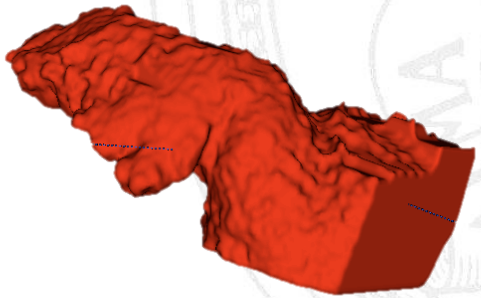
Salt and pepper noise

Median Filter →

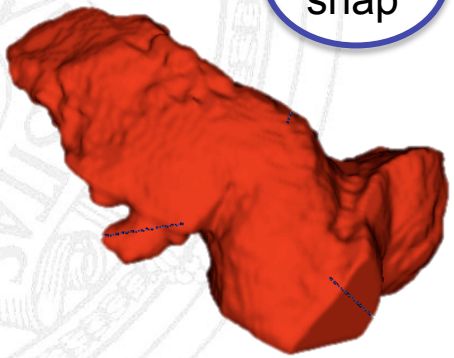
Noise decrease but loss of details

Segmentation flow: Noisy Images (cont.)





Output of *noisy* image segmentation

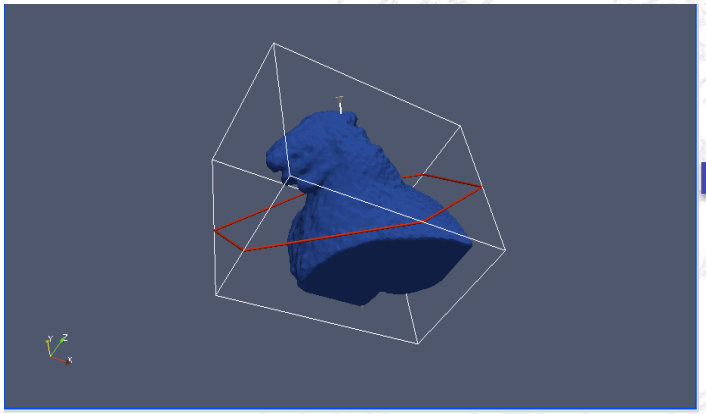


Output of *cleaned* image segmentation

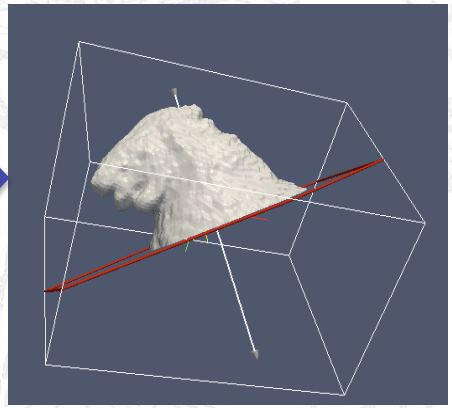
Better image quality ➡ Better segmentation

Post-processing

Cropping → **Goal** → **Printing plate fitting without dimension re-scaled**

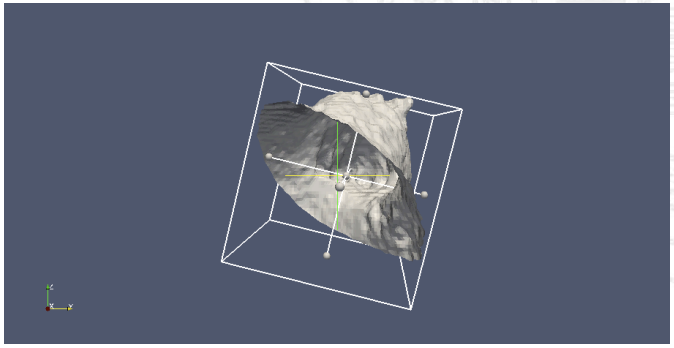


Filter Clip



Interest in LAA and its entrance

Reduce surface dimension



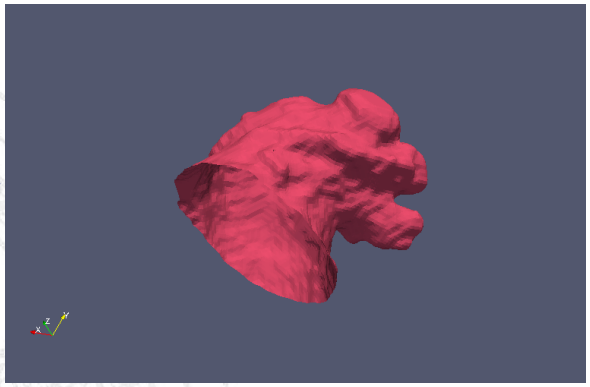
Filter Transform

Fit printing plate dimension

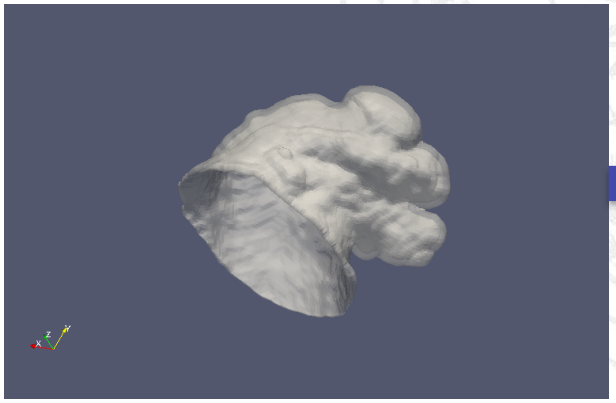
- x = 60 mm
- y = 45 mm
- z = 100 mm

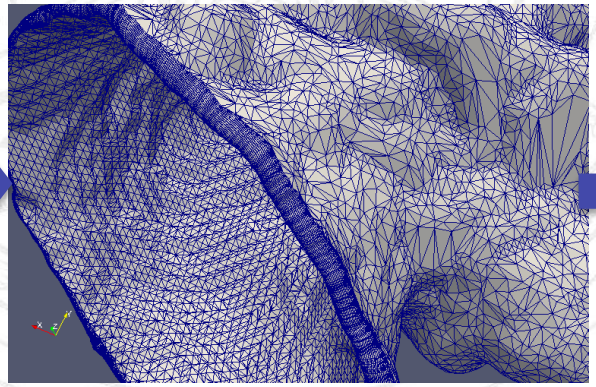
Post-processing (cont.)

Smoothing → **Goal** → **Round the edges**

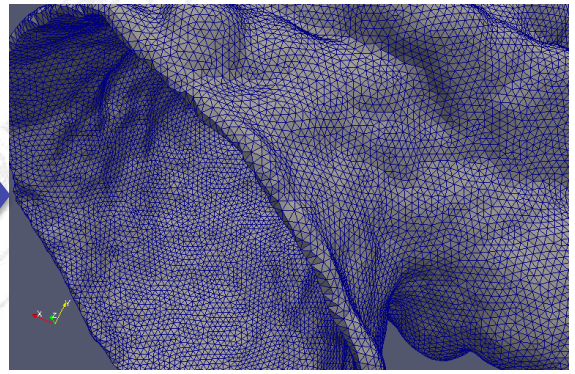


Hollowing → **Goal** → **Thickness (1 mm) to get a closed volume**





Inside creation of the object



Re-meshing

Database Structure

Database ➡ **Overview of information**

Anagrafica	Segmentazione	Immagini	Stampe	GeomAuricola
• Id paz • Nome • Cartella Dicom • Età • Note	• Id paz • Filter • Intensity Mean – SD • Intensity Mean + SD • Voxels • Note	• Id paz • Pixel Spacing • Slice Thickness • Note	• Number • Nome Paz • STL1 • STL2 • Stampa • Note	• Id paz • Diametro • Volume • Morfologia • Note

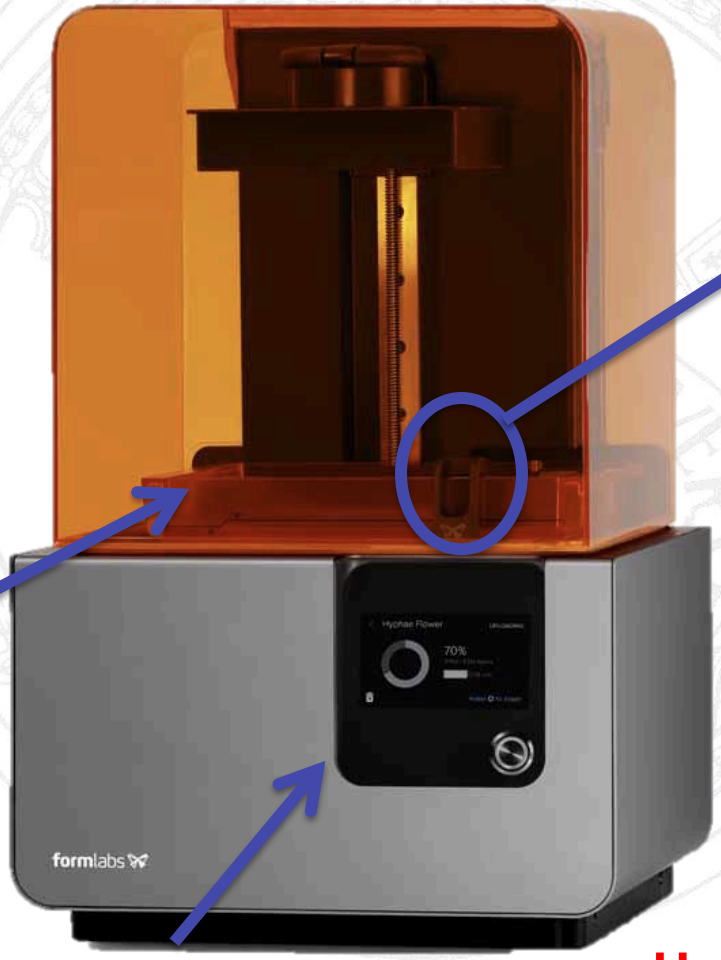
Total images number (*N tot*) = 25

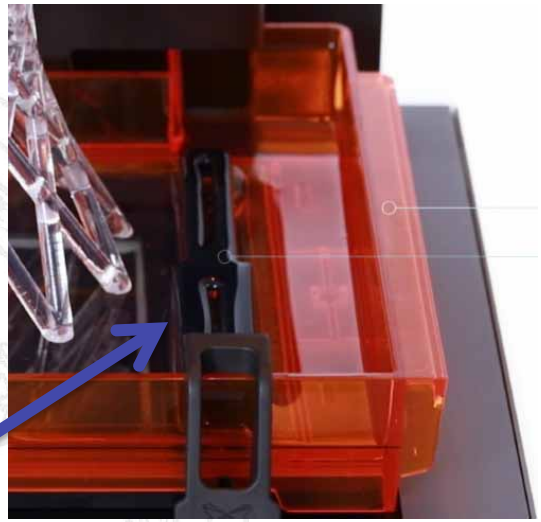
- Good Quality images (*N good*) = 11
- Bad Quality images (*N bad*) = 10
  - Noisy images (*N noise*) = 3
- Others *(post-op…)* = 4

3D Printing: Printer

3D printer: **Form 2** formlabs

Ink:
Polymeric Resin





Resin Wiper
Improve print consistency by removing any particulates from the build area

Heated Tank
Keep resin to a Consistent temperature (35°C)

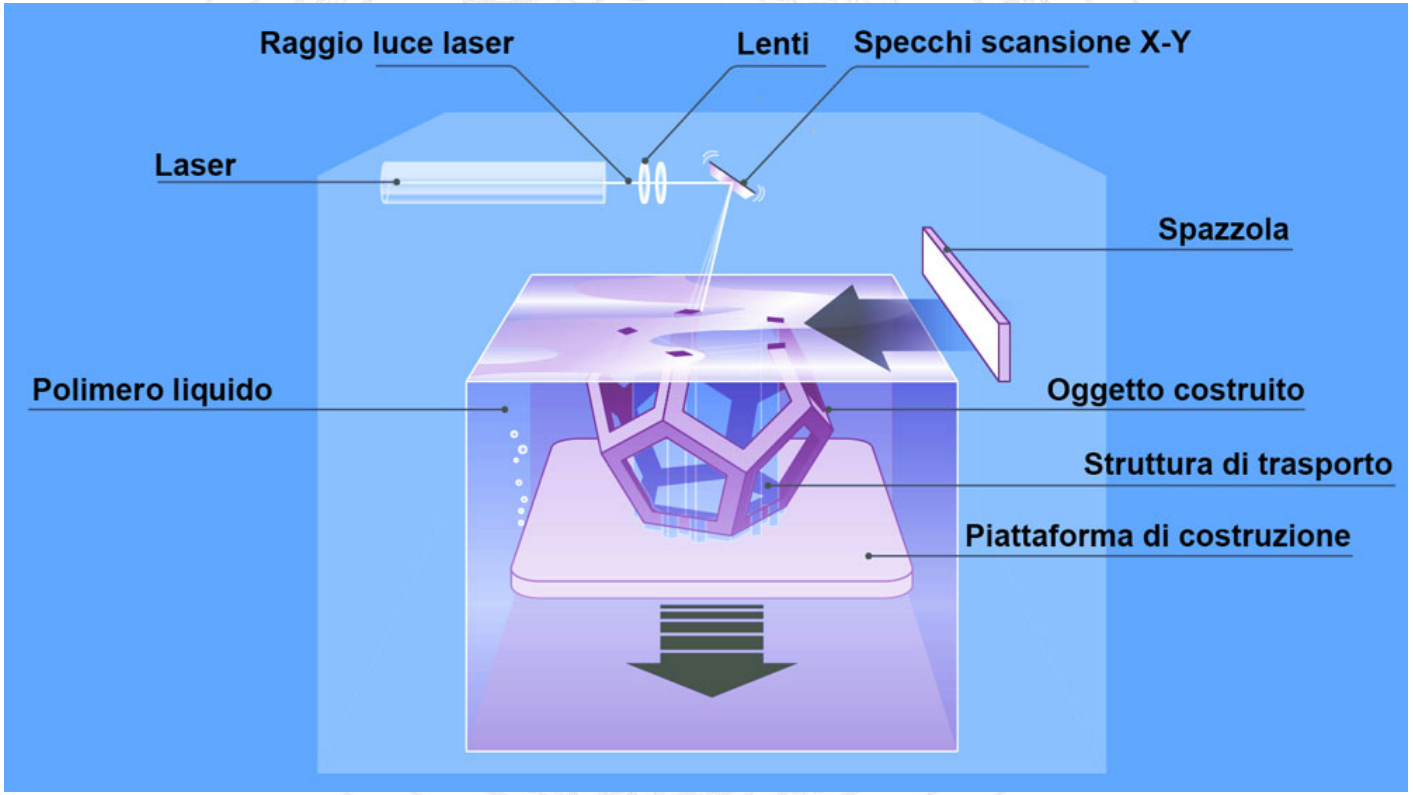
Touch screen interface

How does it work?

3D Printing: Technique

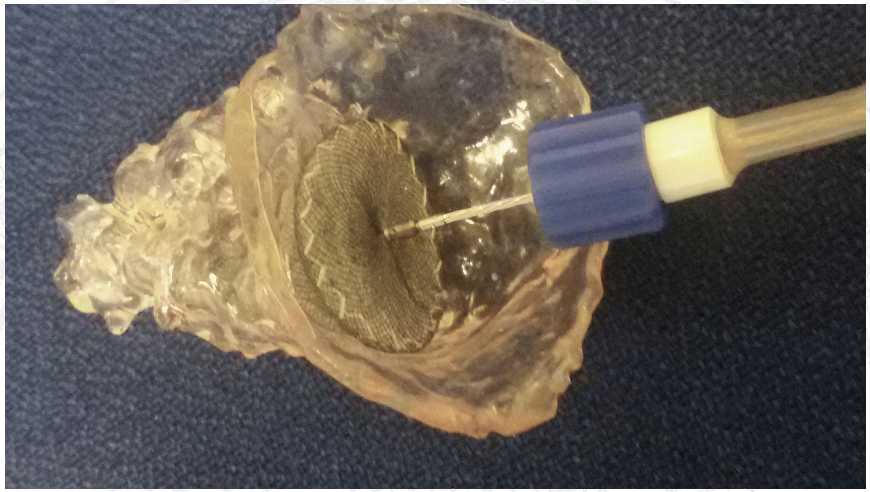
SLA: StereoLithography Apparatus

Optical Engine: 250 mW precision laser guided by custom-built galvanometers



Laser and photopolymer resin ➡ Consolidation

3D Printing: Output



N printed = 14 (11 good quality + 3 pre-processed noisy images)

Segmentation, Post – Processing and 3D Printing

PATIENT – SPECIFIC MODEL

Conclusion: Future Prospect

Statistics:

F.A. effect — World → 2% of people (6 million in Europe)

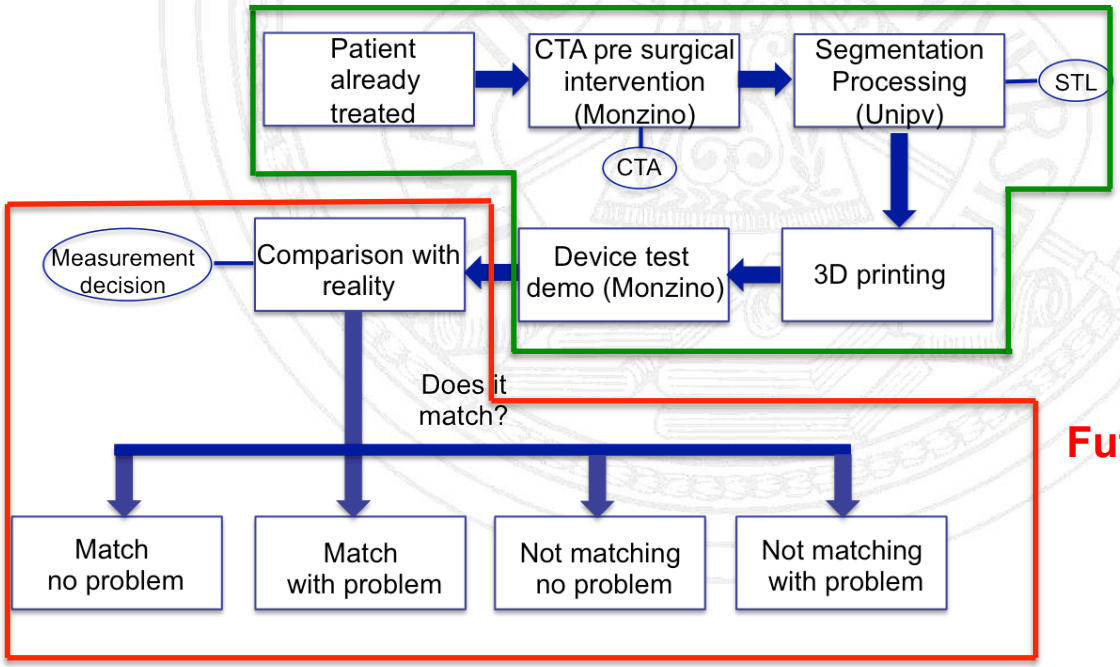
Correlation with Age — Age ≥ 60 years old → 4%

Age ≥ 80 years old → 9%

Exponential trend

Endovascular treatment:

Nowadays studies : Residual leaks in 10% of patients → **How to improve this result?**



Goal reached

Future prospect

Conclusion: Personal Growth

Start

Scientific Articles

Study case

from literature to practice

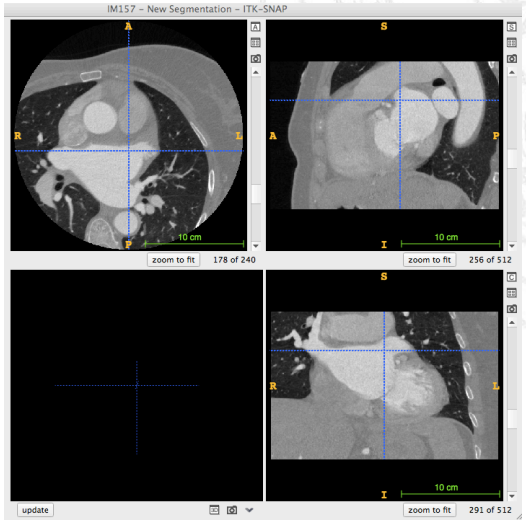
Image elaboration

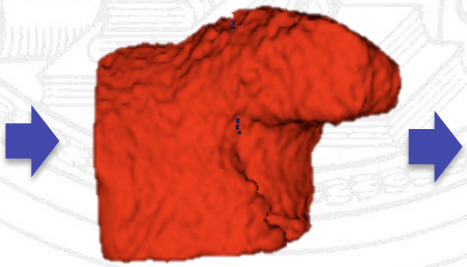
Actual clinical cases

Better knowledge of 3D printing
and its usage in pre-procedural stage

Interest in going on studying 3D printing application
in biomedical setting

End





…GRAZIE PER L'ATTENZIONE !!!

Un ringraziamento particolare al Dott. M. Conti

… Some more information …

Local filters

As for noisy image:

Smoothing Filter

Delete the sudden transitions of luminance

- Reduced noise
- Details loss

- Mean Filter
- Gaussian Filter
- Median Filter

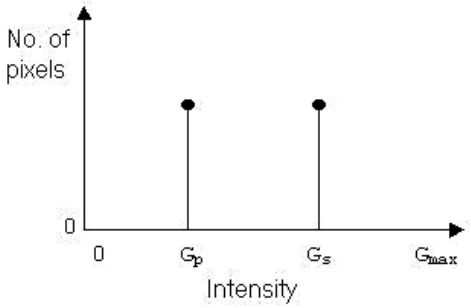
Median filter

Feature:

Working well to remove impulsive noise

Less image alteration than other smoothing filters

Parameter: Neighbourhood Radius



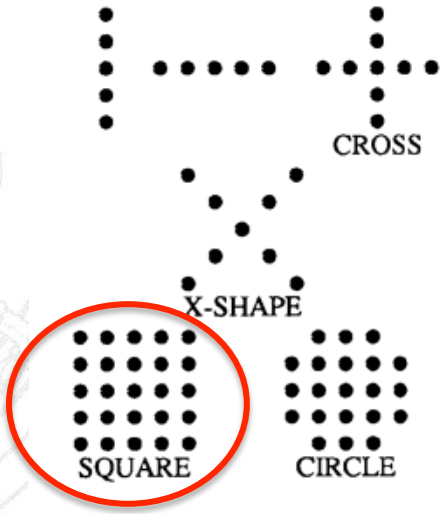
Original Intensities

3	3	4
4	87	4
4	5	5

Sorted Pixel values: 3, 3, 4, 4, 4, 4, 5, 5, 87

Median filtered value: 4

Type of mask



Mask used: square3X3

Matlab script

1. Metadata

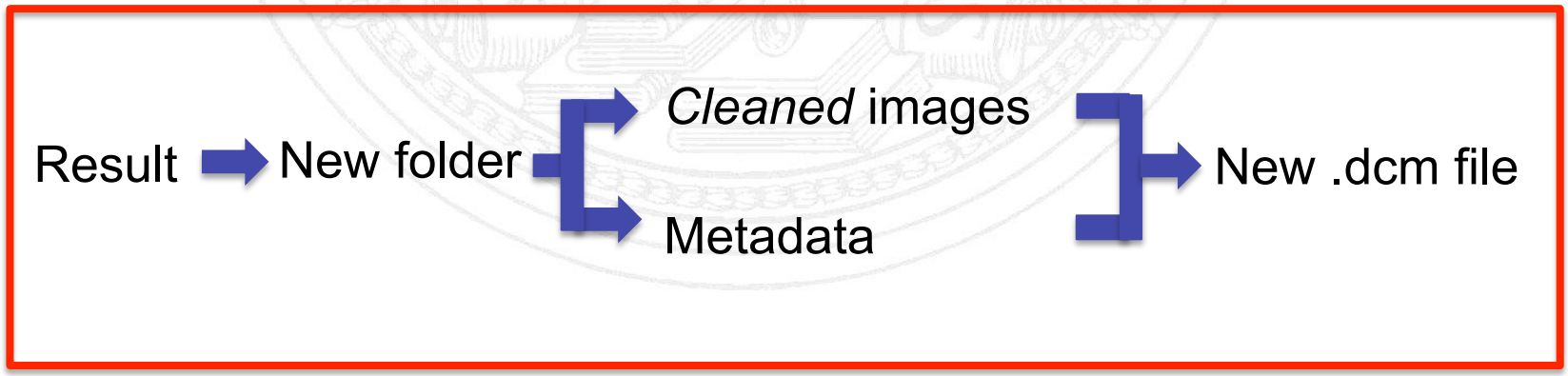
```
%% Carico le Dicom originali

cd(dirOrig);
fn='IM';

%Dati relativi alla prima dicom
fn_tmp=[fn num2str(0)];
%fn_tmp=IM(i) i=[0 n]
dh(1)=dicominfo(fn_tmp);

ImgOrig=zeros(dh(1).Width,dh(1).Height,n+1);
ImgOrig(:,:,1) = dicomread(fn_tmp);

%Ciclo per aggiornare
%i metadata e le immagini
for i=1:n
    fn_tmp=[fn num2str(i)];

    %salvo i metadata nella matrice
    dh(i+1)=dicominfo(fn_tmp);

    ImgOrig(:,:,i+1) = dicomread(fn_tmp);
end

cd(wkdir); %torno alla wkdir
```

2. Pre-processed Images

```
%% Carico le immagini ripulite

cd(dirMod); %cambio directory
ImgMod=zeros(dh(1).Width,dh(1).Height,n+1);

%prima immagine modificata
fn_tmp=[fn num2str(0) '.tif'];

ImgMod(:,:,1) = imread(fn_tmp);

%Ciclo che riempie la matrice con tutte
%le immagini modificate
for i=1:n
    fn_tmp=[fn num2str(i) '.tif'];
    ImgMod(:,:,i+1) = imread(fn_tmp);
end

%plot della prima slice
figure(2)
subplot(1,2,1)
imagesc(ImgOrig(:,:,1))
subplot(1,2,2)
imagesc(ImgMod(:,:,1))
colormap gray

cd(wkdir); %torno alla wkdir
```

3. New File

```
%% Scrittura del nuovo file

cd('New');

fn_tmp=[fn num2str(0) '.dcm'];

for i=1:n


    fn_tmp=[fn num2str(i) '.dcm'];

    dicomwrite(uint16(ImgMod(:,:,i)),fn_tmp,dh(i),'CreateMode','copy');
    %scrivo un nuovo file dove unisco le immagini modificate e i metadata
    %recuperati da immagini originali
end
```



Form 2 Formlab: Specification

Build volume: 145x145x175

Layer thickness: 25-100 micros

Laser spot size: 140 micros

Laser power: 250 mW

Automated Resin system

Level sensing: Tank automatically filled

Cartridge ID chips: keep track of resin supplies

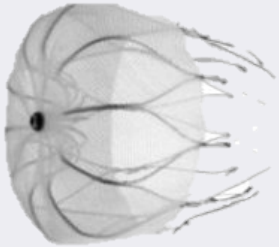
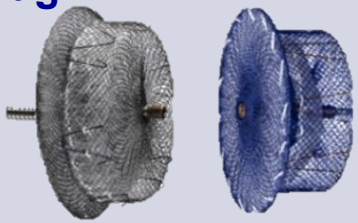
Open Mode: experiment with 3rd party resins

Controls

Touchscreen interface

Wirless connectivity

Devices

Dispositivo	Terapia Pre-operatoria	Terapia Post-operatoria	Trial Clinici
PLAATO	Aspirina + Clopidrogel	Aspirina → a vita	Ostermayer et al. Bayard et al. Block et al.
Watchman 	Non richiesta	Warfarin → 6 settimane Aspirina + Clopidrogel → 6 mesi	PROTECT AF CAP ASAP
Amplatzer Cardiac Plug 	Aspirina + Clopidrogel	Aspirina + Clopidrogel→ 1 mese Aspirina → 5 mesi	Park et al.