


XXXII CONGRESSO NAZIONALE AIRO  
XXXIII CONGRESSO NAZIONALE AIRB  
XII CONGRESSO NAZIONALE AIRO GIOVANI

# AIRO2022

Radioterapia di precisione per un'oncologia innovativa e sostenibile

BOLOGNA, 25-27 NOVEMBRE  
PALAZZO DEI CONGRESSI

 Associazione Italiana  
Radioterapia e Oncologia clinica

 Società Italiana di Radiobiologia

 Associazione  
Italiana  
Radioterapia  
e Oncologia  
clinica  


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Radioterapia di precisione per un'oncologia innovativa e sostenibile

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**AUTOPLANNING E FUSIONE DI IMMAGINI: STATO DELL'ARTE,  
PROSPETTIVE E PITFALLS**

## Image Registration

**Gemelli**



Fondazione Policlinico Universitario A. Gemelli  
Università Cattolica del Sacro Cuore

**ART**

Advanced Radiation  
Therapy

Nicola Dinapoli

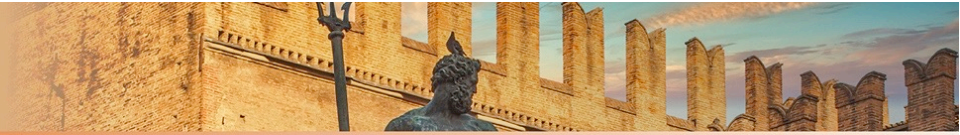


Associazione Italiana  
Radioterapia e Oncologia clinica



Società Italiana di Radiobiologia





## DICHIARAZIONE

Relatore: Nicola Dinapoli

Come da nuova regolamentazione della Commissione Nazionale per la Formazione Continua del Ministero della Salute, è richiesta la trasparenza delle fonti di finanziamento e dei rapporti con soggetti portatori di interessi commerciali in campo sanitario.

- Posizione di dipendente in aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE)**
- Consulenza ad aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE)**
- Fondi per la ricerca da aziende con interessi commerciali in campo sanitario **(Varian Medical System)**
- Partecipazione ad Advisory Board **(NIENTE DA DICHIARARE)**
- Titolarità di brevetti in compartecipazione ad aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE)**
- Partecipazioni azionarie in aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE)**
- Altro



**Definition:** image registration is the process of transforming different sets of data into one coordinate system. Data may be multiple photographs, data from different sensors, times, depths, or viewpoints. Registration is necessary in order to be able to compare or integrate the data obtained from these different measurements.

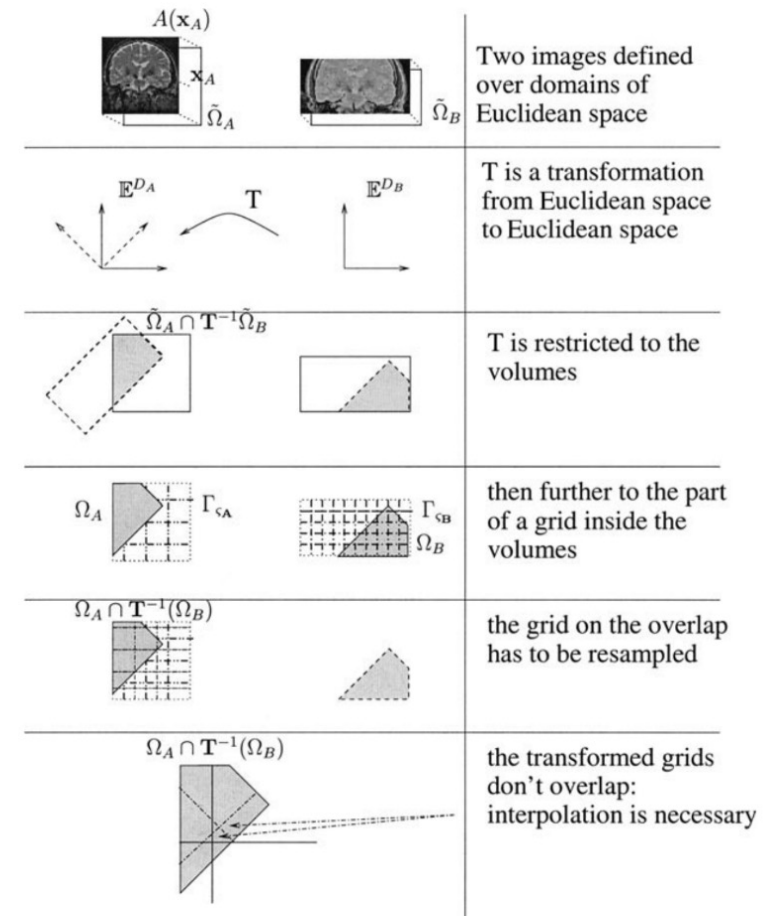
Richard Szeliski, *Image Alignment and Stitching: A Tutorial*. Foundations and Trends in Computer Graphics and Computer Vision, 2:1-104, 2006.



## Rigid registration:

1. scaling
2. 6 degree of freedom roto-translation
3. interpolation

Hajnal, J. V., Hill, D. L. G., & Hawkes, D. J. (2001).  
 Medical image registration. *Medical Image Registration*,  
 46, 1–383.



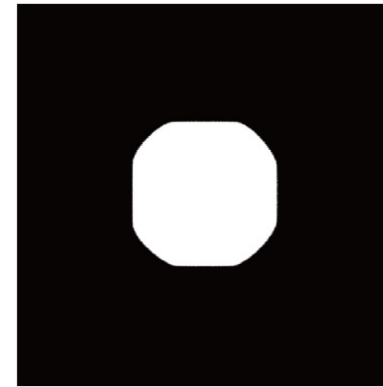


## Deformable registration:

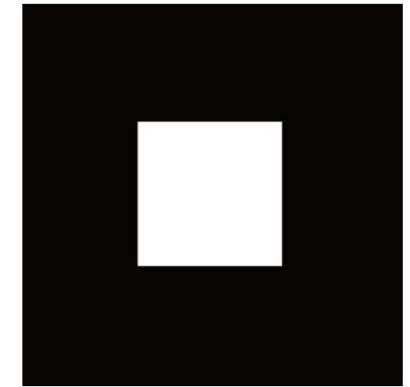
Identifies the spatial correspondence in order to minimize the differences between two or among multiple sets of images.

It introduces geometric *transformation*.

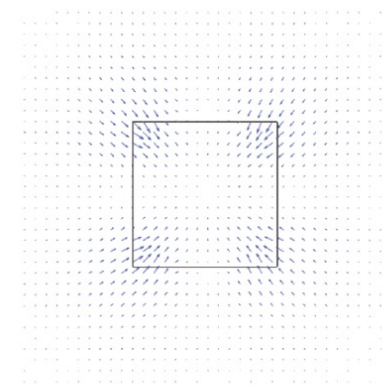
Dowling, J. A., & O'Connor, L. M. (2020). Deformable image registration in radiation therapy. *Journal of Medical Radiation Sciences*, 67(4), 257–259.



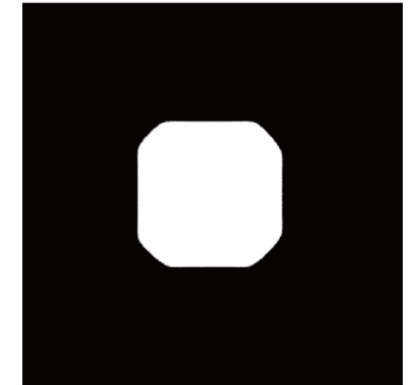
A



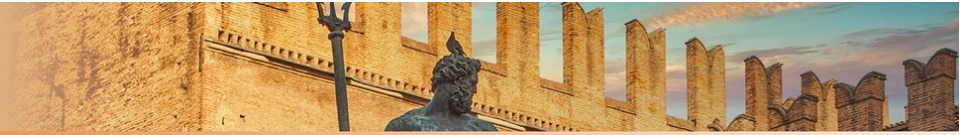
B



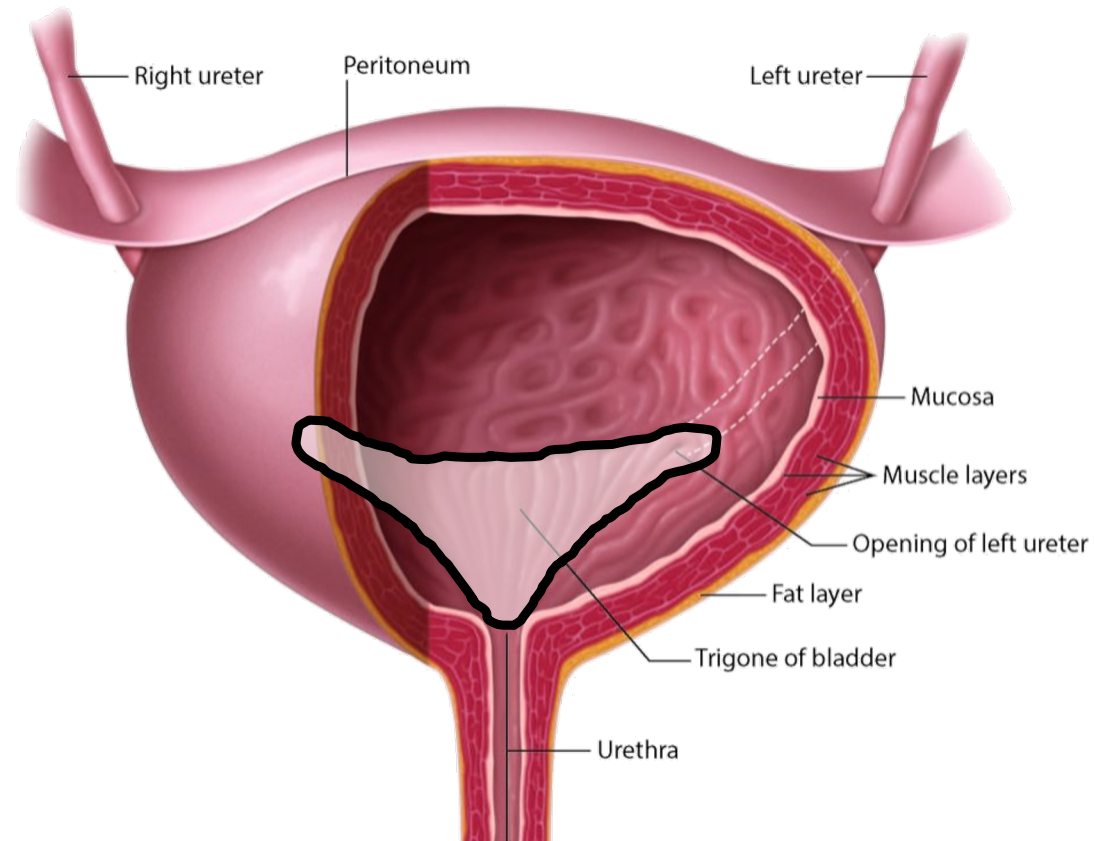
C

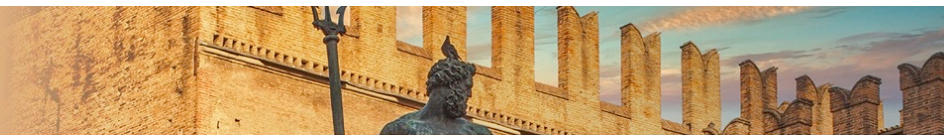


D

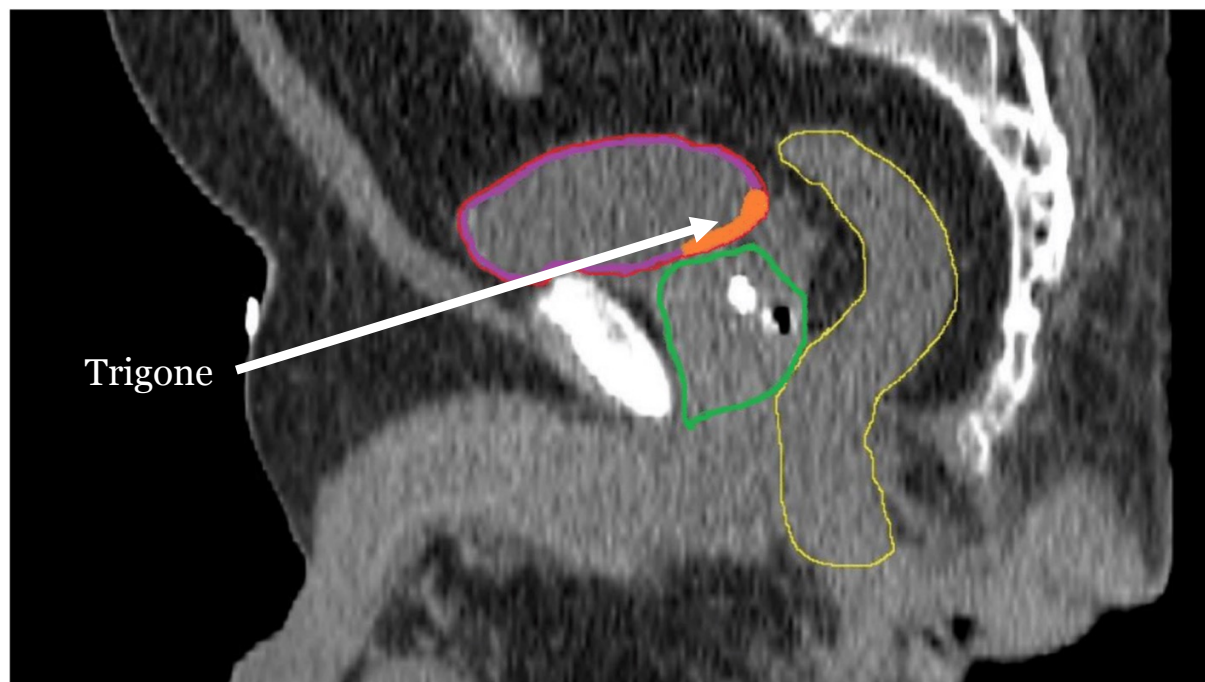


## Deformable registration: The “bladder case”





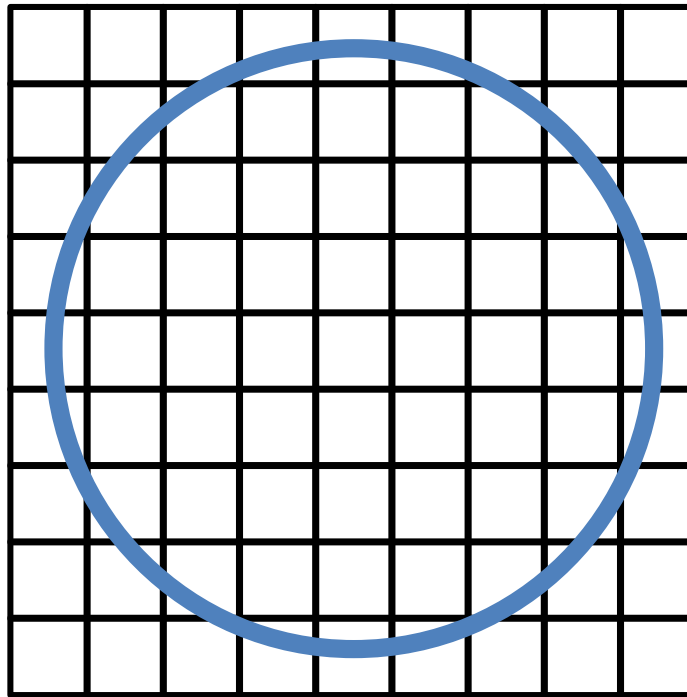
## Deformable registration: The “bladder case”

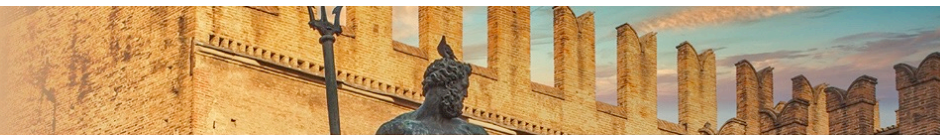




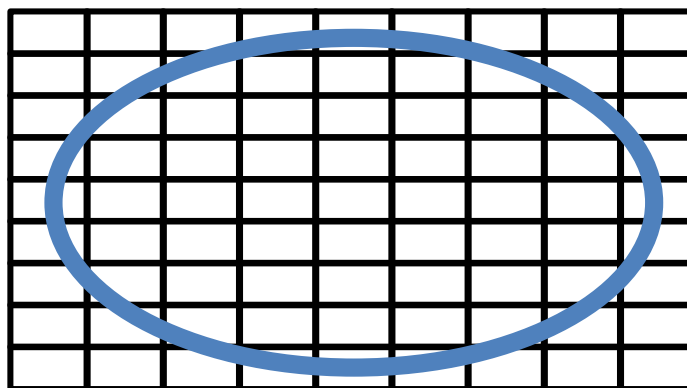


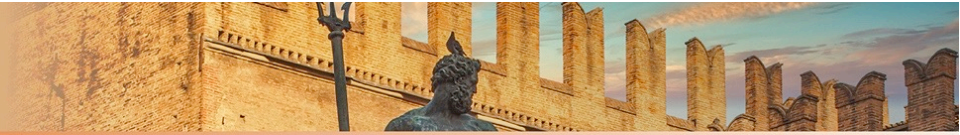
## How does bladder deform itself?



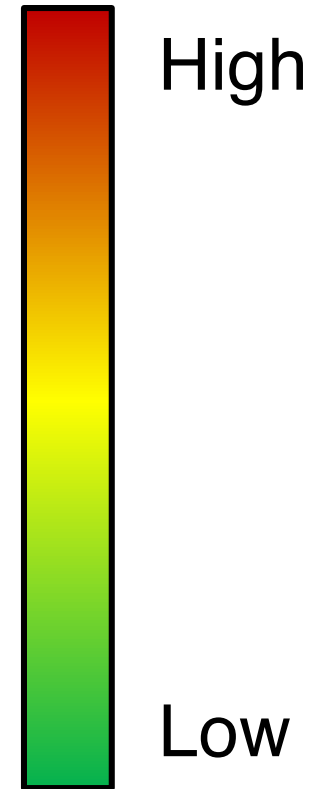
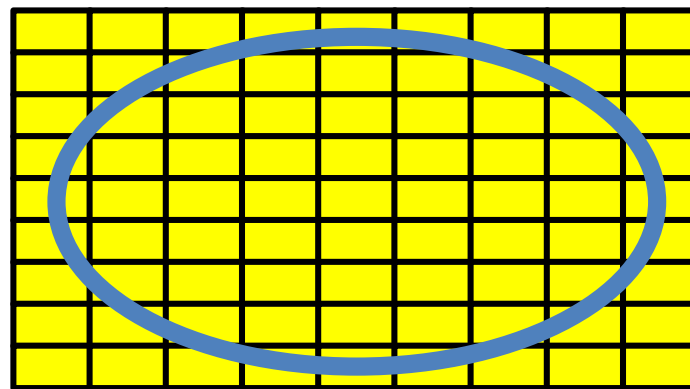


## How does bladder deform itself?



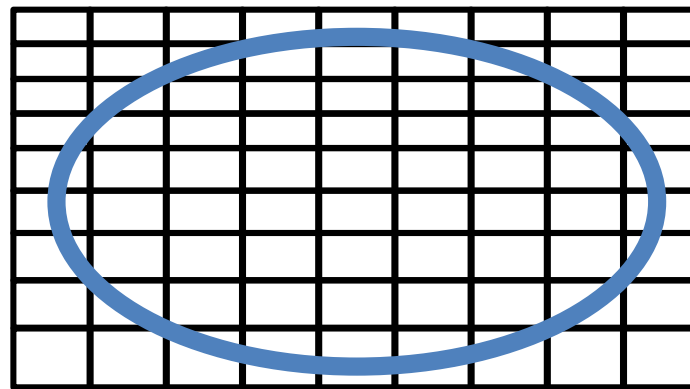


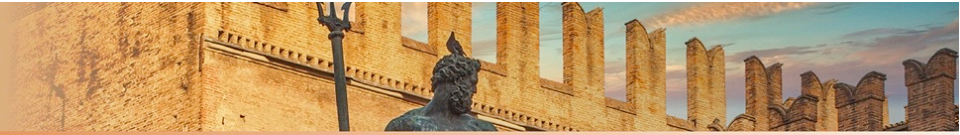
## How does bladder deform itself?



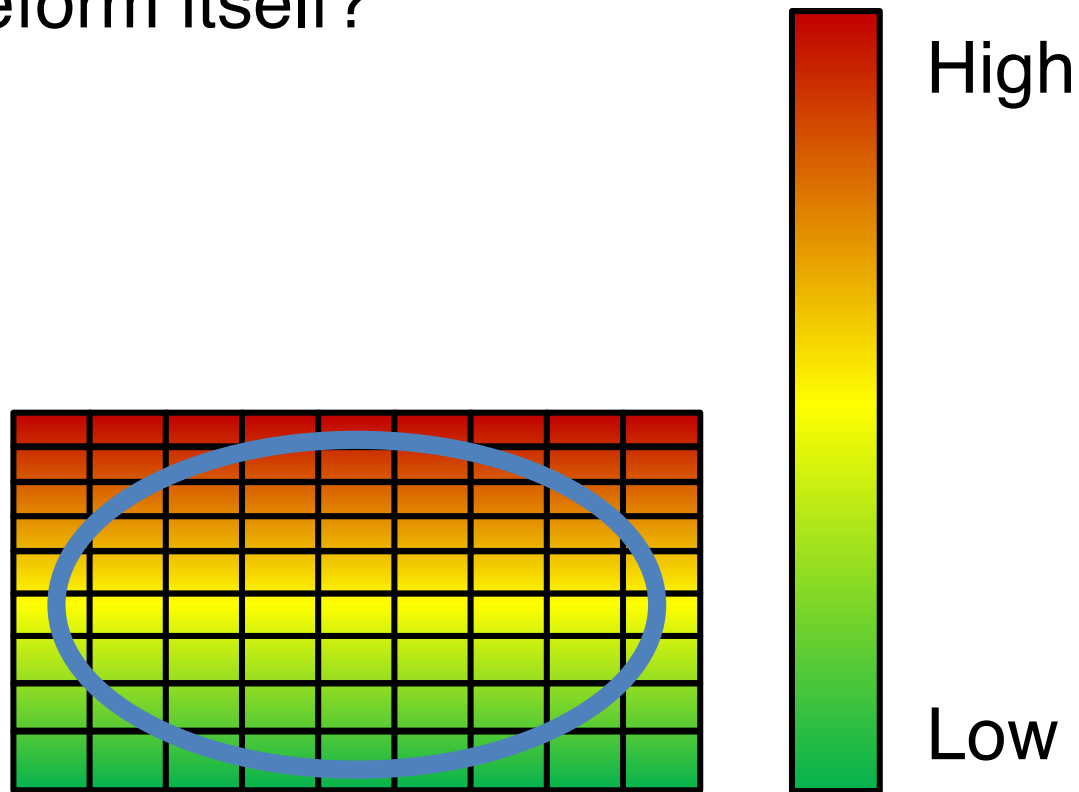


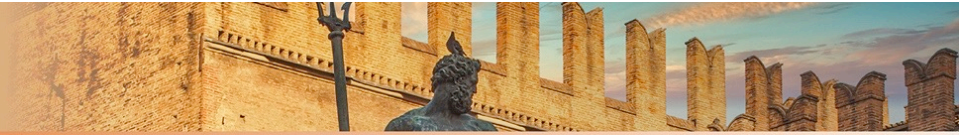
## How does bladder deform itself?





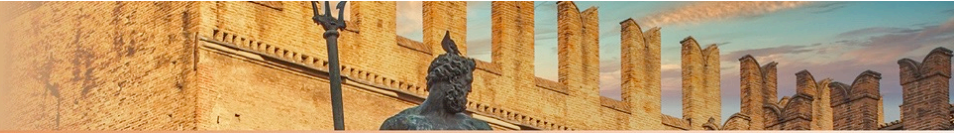
## How does bladder deform itself?



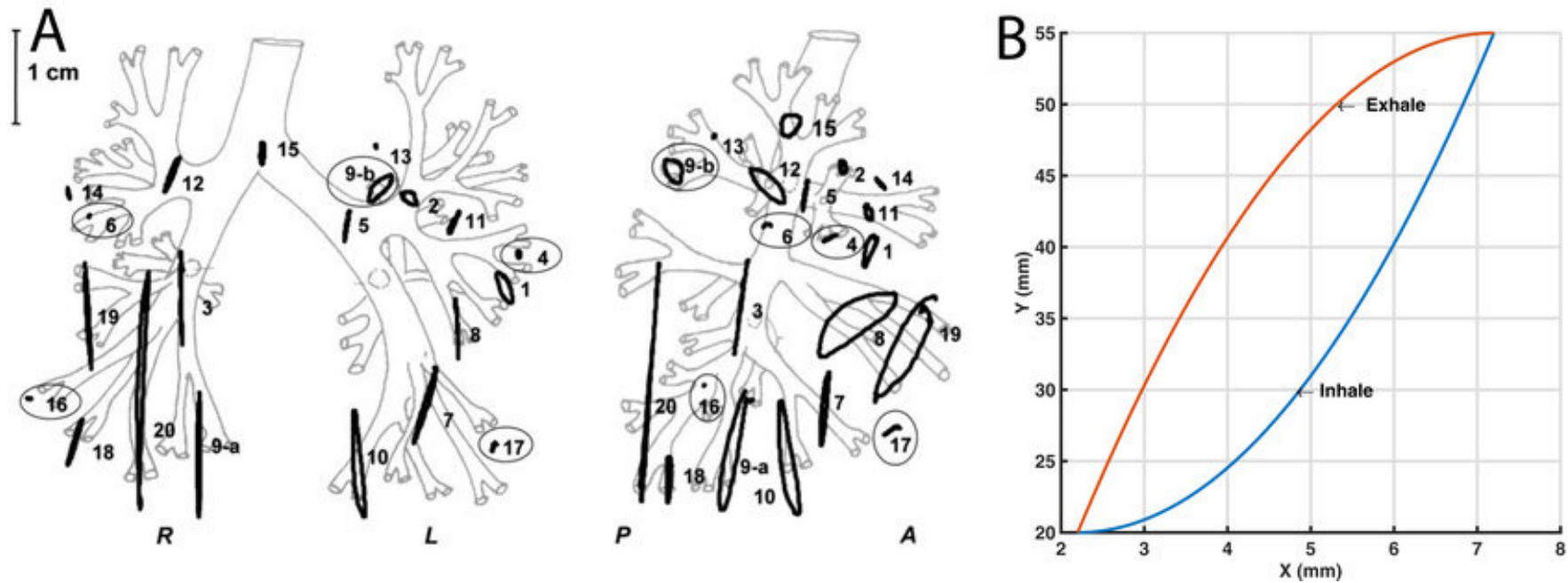


These artifacts can affect different steps in radiotherapy planning and treatment:

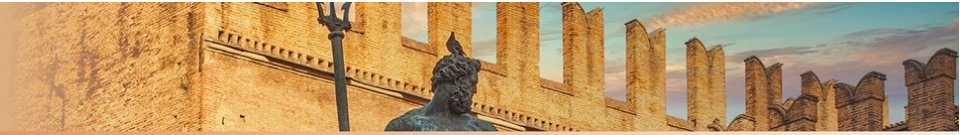
- 1) Structure reconstruction (e.g. by CBCT)
- 2) Online and offline adaptation
- 3) Online and offline dose distribution adaptive summation
- 4) Hollow organs or lungs registrations



## Lung hysteresis



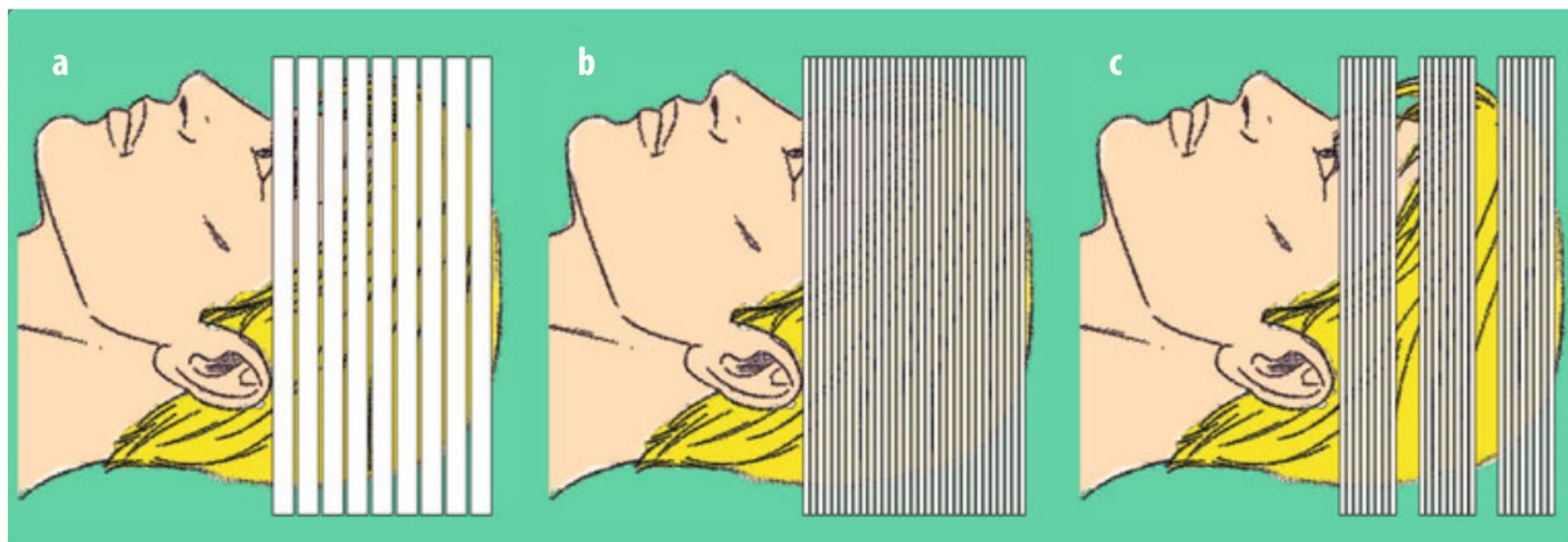
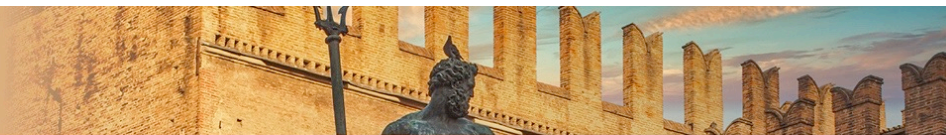
Escolar, J. D. D., & Escolar, A. (2004). Lung hysteresis: A morphological view. *Histology and Histopathology*, 19(1), 159–166.



## Image registration problems: what kind of imaging?

1. MR for brain – choose the sequence according delineation needs (T1c – T2 – FLAIR – FSPGR)
2. MR for brain – 3D or 2D?



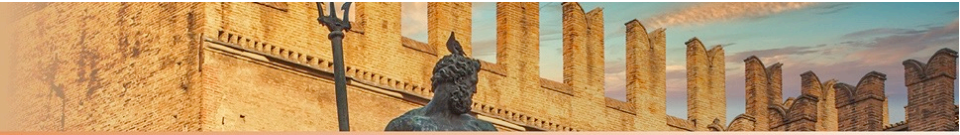


2D

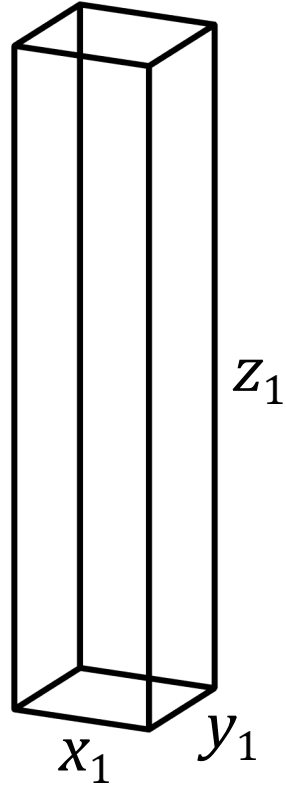
3D

3D - multislabs

Coriasco M, et al., Elementi di Risonanza Magnetica, Springer, 2014



$$z_1 > x_1, y_1$$

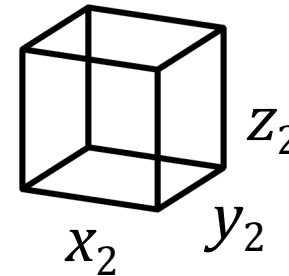


2D

Morphological  
T1 – T2\*

$$x_1 < x_2$$

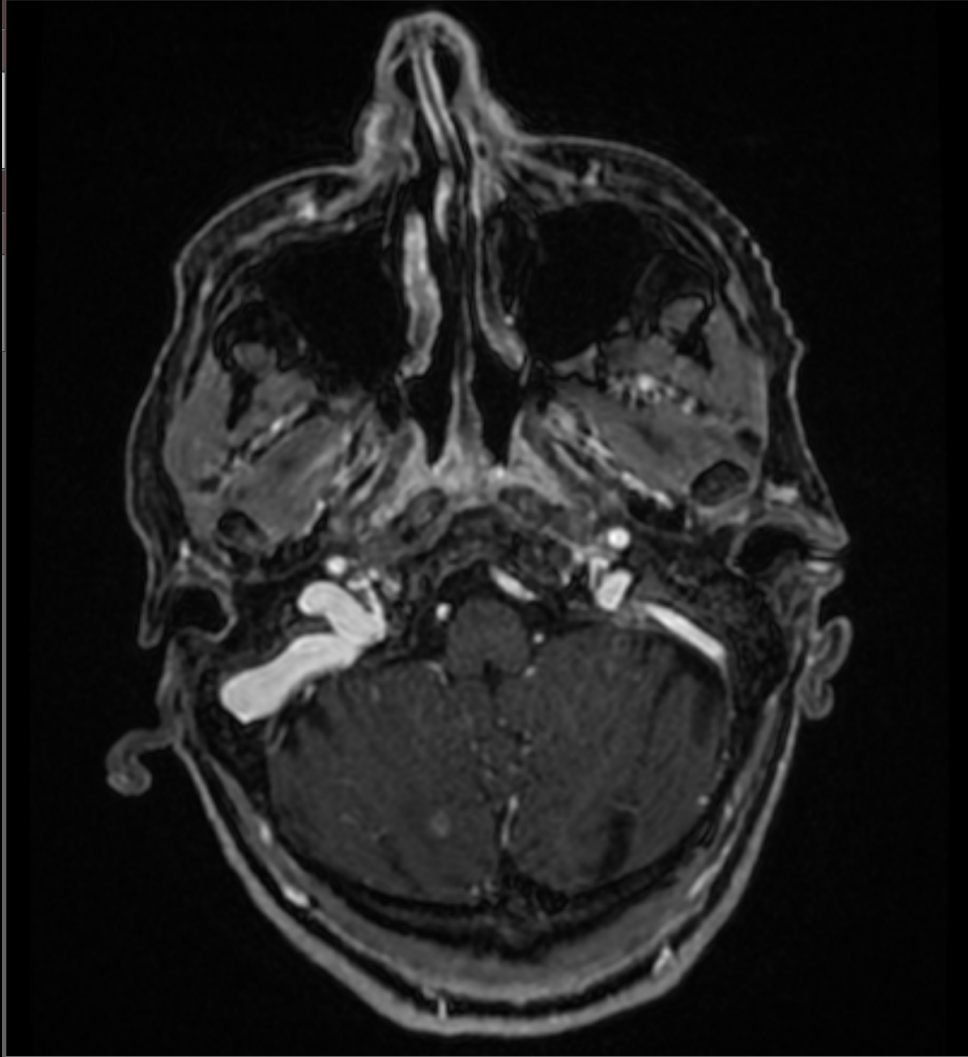
$$z_2 = x_2, y_2$$



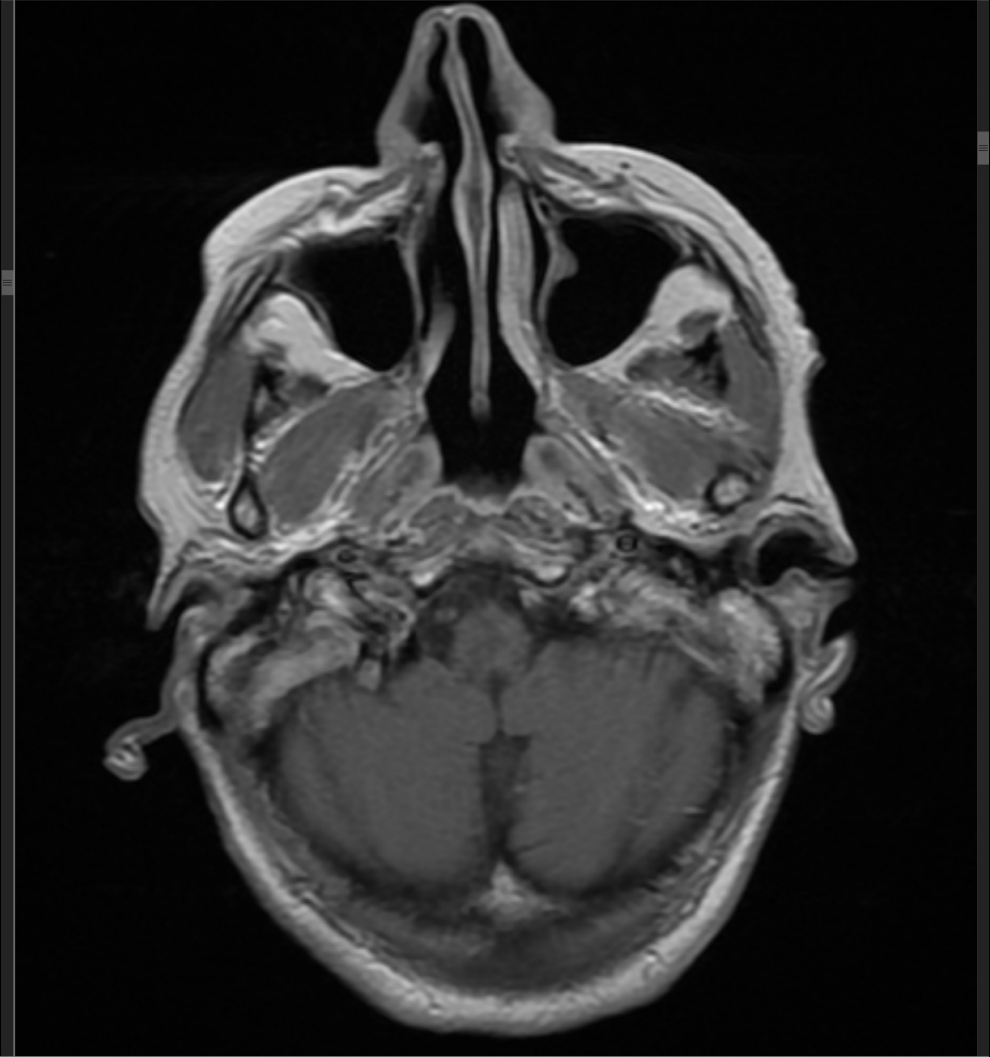
3D

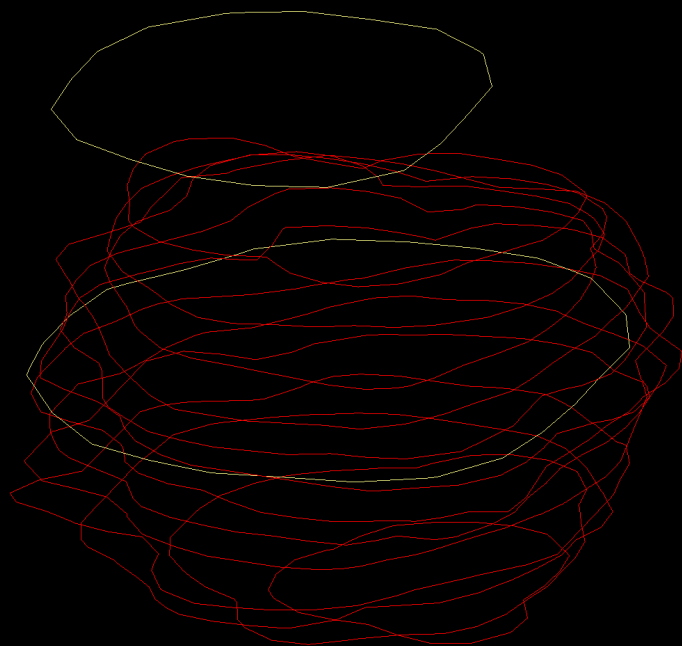
3D FSPGR

ANONYMOUS 000001 - 06/06/2017 17:50:01



ANONYMOUS 000002 - 06/06/2017 17:50:01





Wires



3D model

# Partial volume artifact

Signal  
Intensity

Z coordinates FSPGR

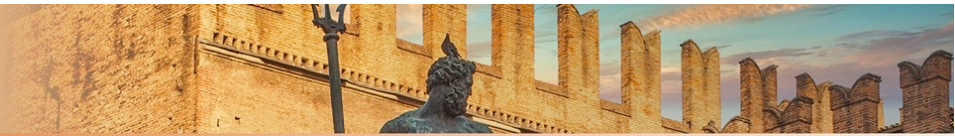
FSPGR z	FSPGR val	T1c val	T1c z
0	10	68	0
0,5	12	68	0
1	15	68	0
1,5	27	68	0
2	28	68	0
2,5	26	68	0
3	168	68	0
3,5	258	68	0
4	285	160,375	4
4,5	284	160,375	4
5	274	160,375	4
5,5	223	160,375	4
6	78	160,375	4
6,5	64	160,375	4
7	52	160,375	4
7,5	23	160,375	4
8	10	22,5	8
8,5	7	22,5	8
9	12	22,5	8
9,5	78	22,5	8
10	15	22,5	8
10,5	33	22,5	8
11	15	22,5	8
11,5	10	22,5	8

Z coordinates T1c

Consider a voxel that contains fractional amounts  $f_A$  and  $f_B$  of two materials, A and B. The MR signal from the entire voxel ( $SV$ ) will then reflect the **weighted average** of signals  $S_A$  and  $S_B$  from the two components

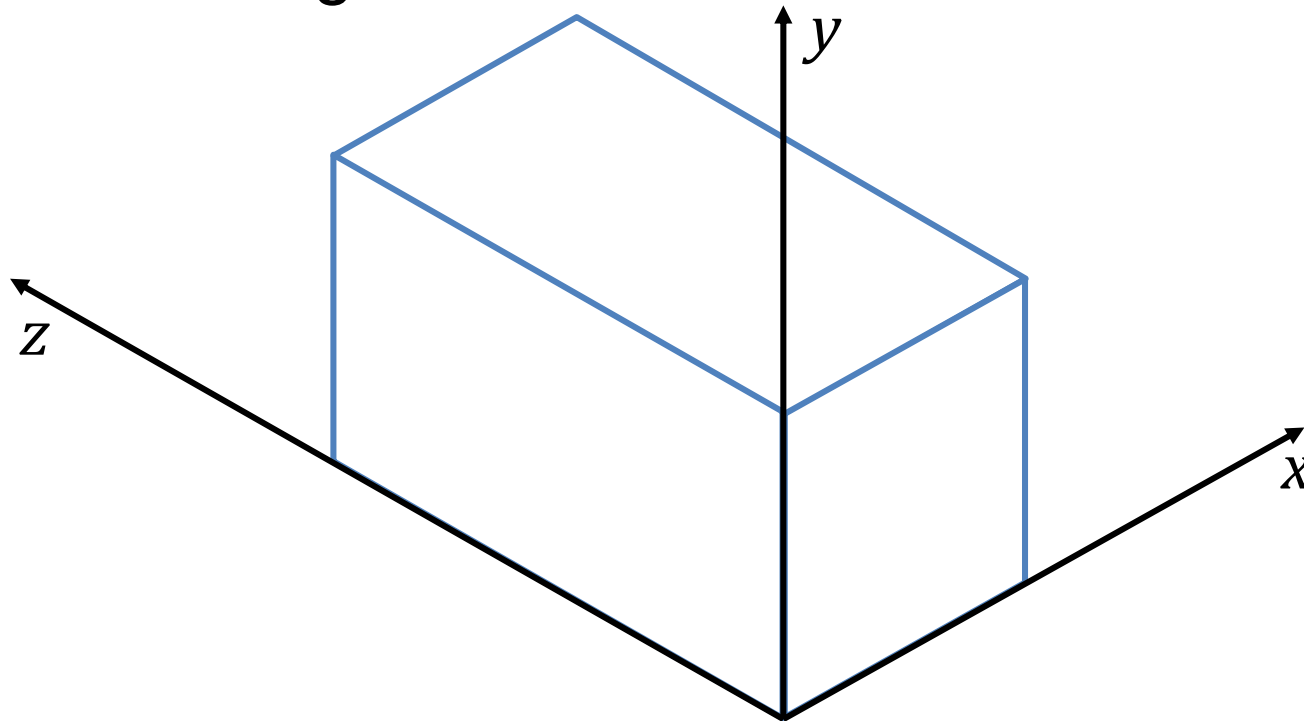
$$SV = f_A S_A + f_B S_B$$

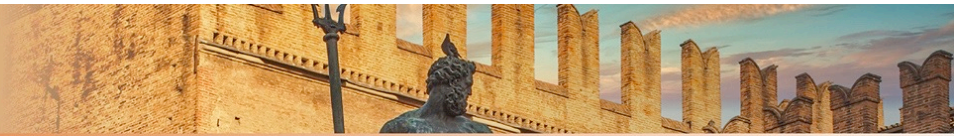
Imperfect RF-pulse profiles may also cause to partial volume effects by exciting tissues outside the desired slice. When multiple slices are placed side by side, this interference is known as **cross-talk**.



## Image registration problems: geometry inconsistencies

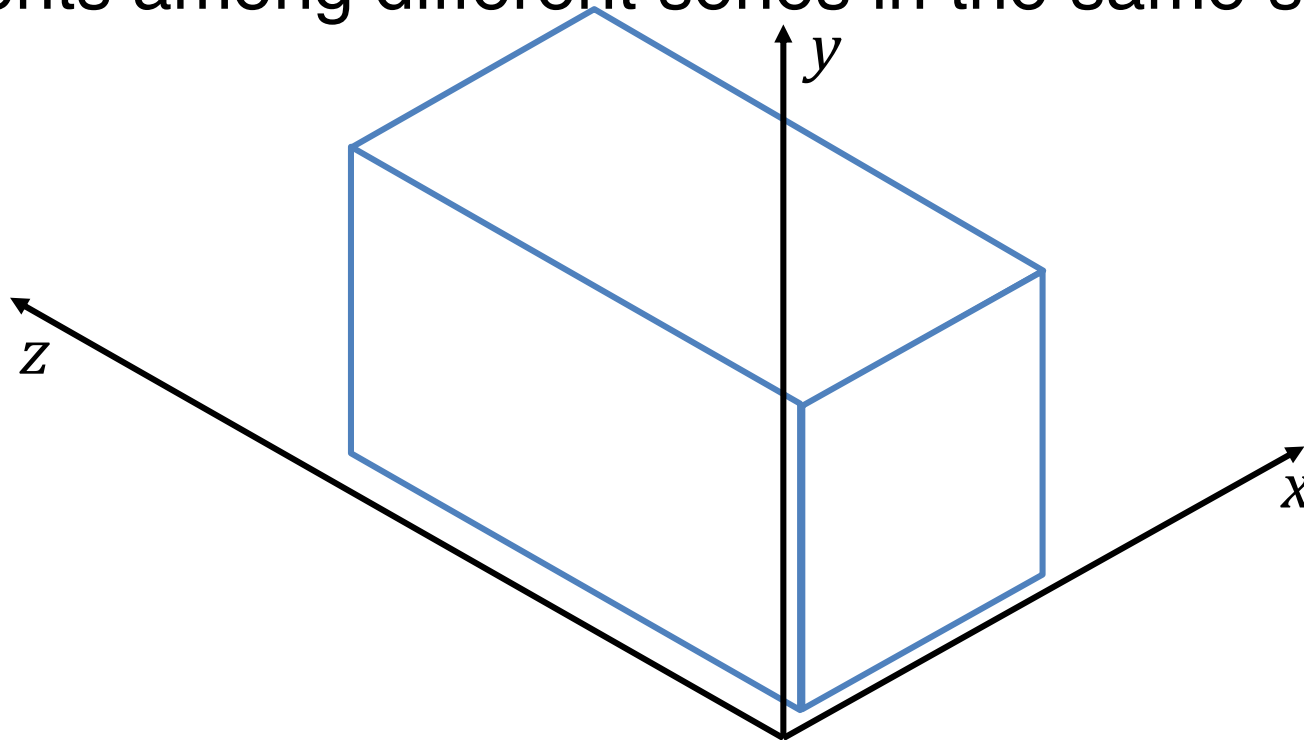
### 1. Movements among different series in the same study (MR)

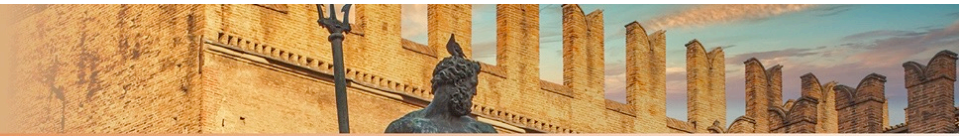




## Image registration problems: geometry inconsistencies

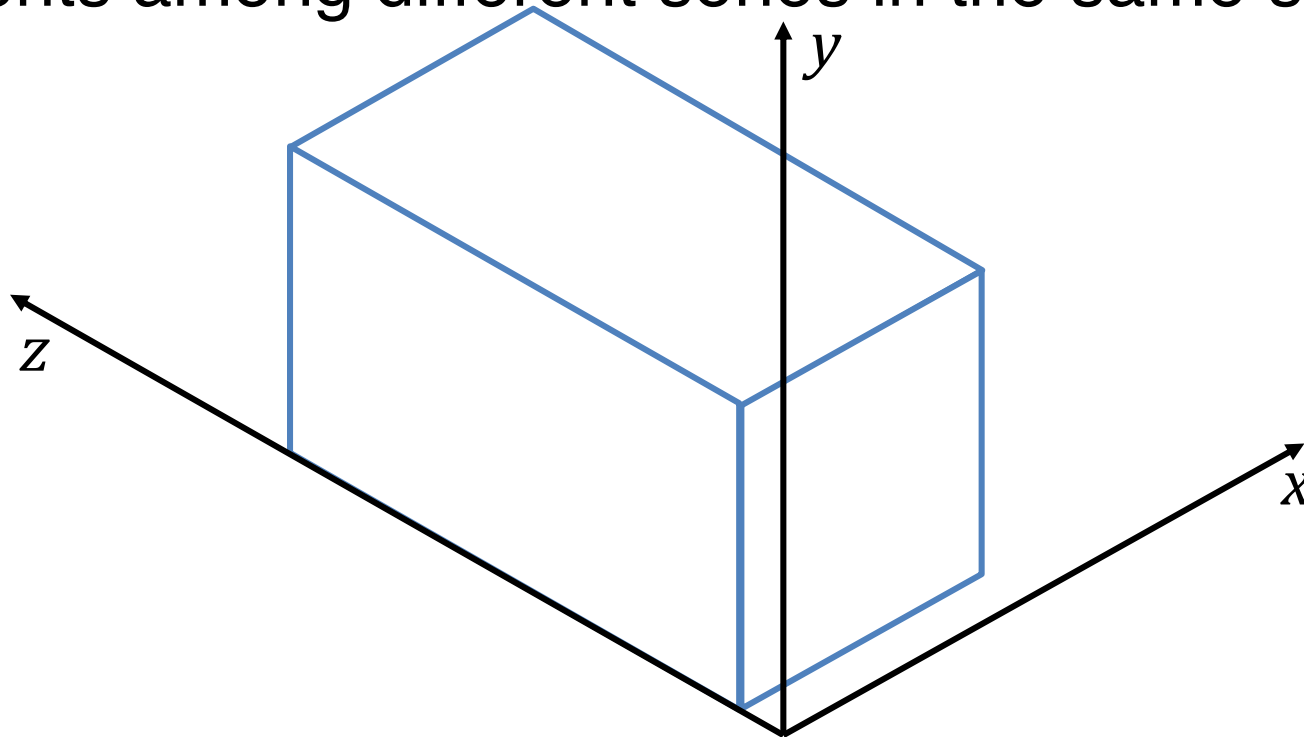
### 1. Movements among different series in the same study (MR)



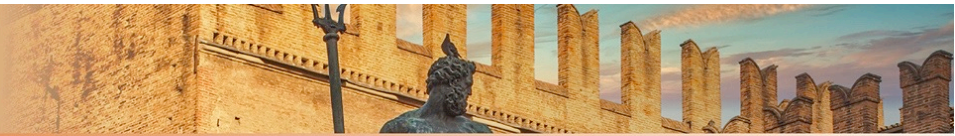


## Image registration problems: geometry inconsistencies

### 1. Movements among different series in the same study (MR)

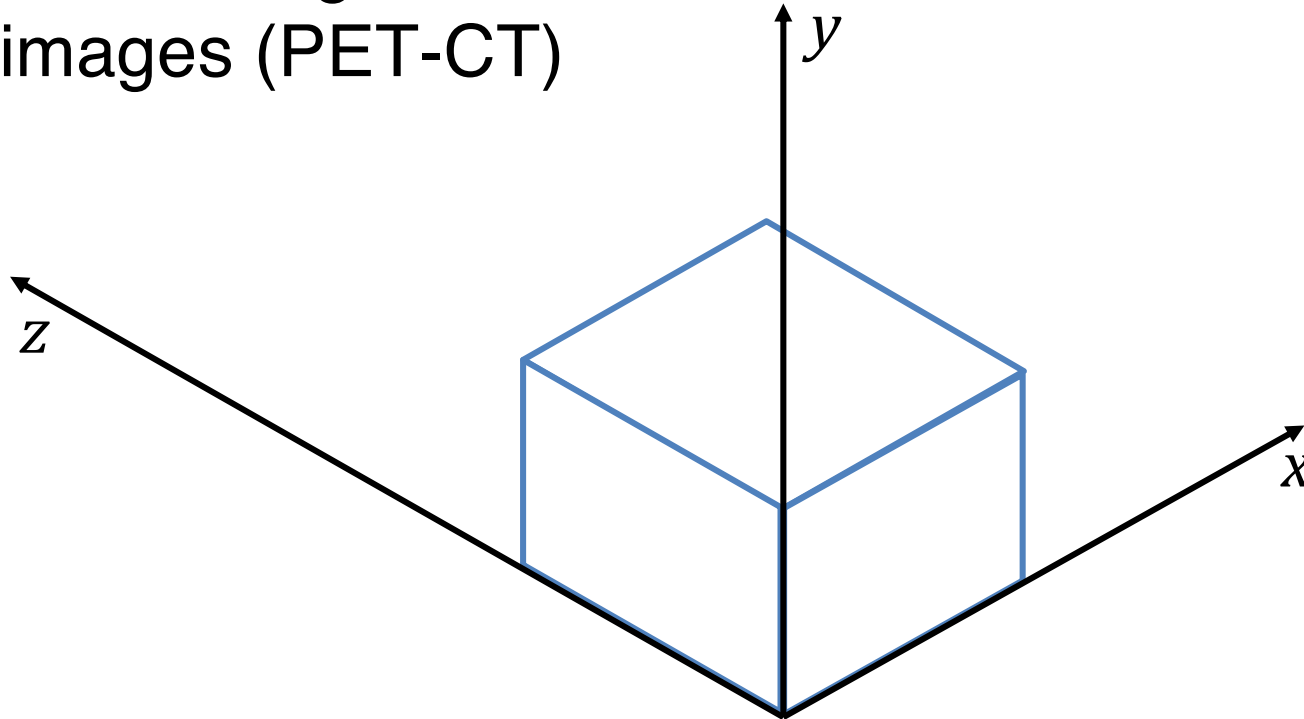


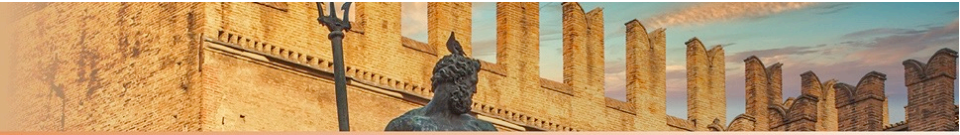




## Image registration problems: geometry inconsistencies

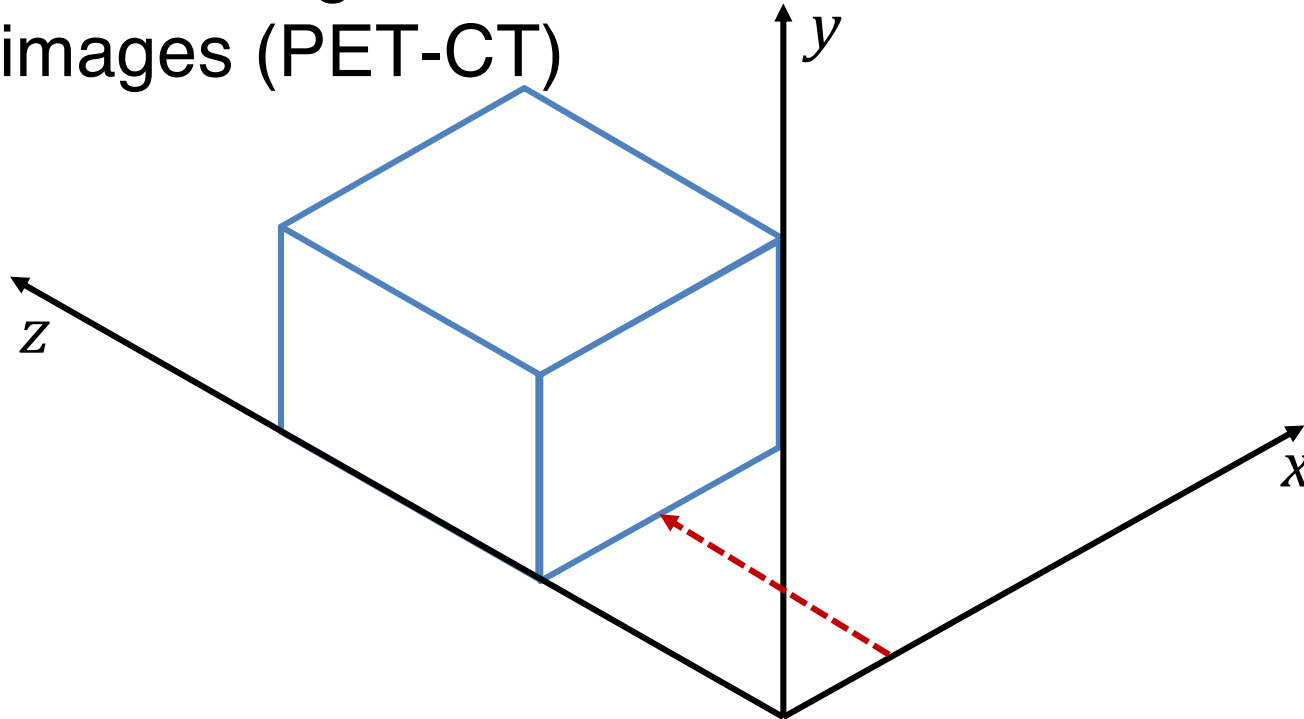
### 1. Movements among different series DICOM coordinates registered images (PET-CT)





## Image registration problems: geometry inconsistencies

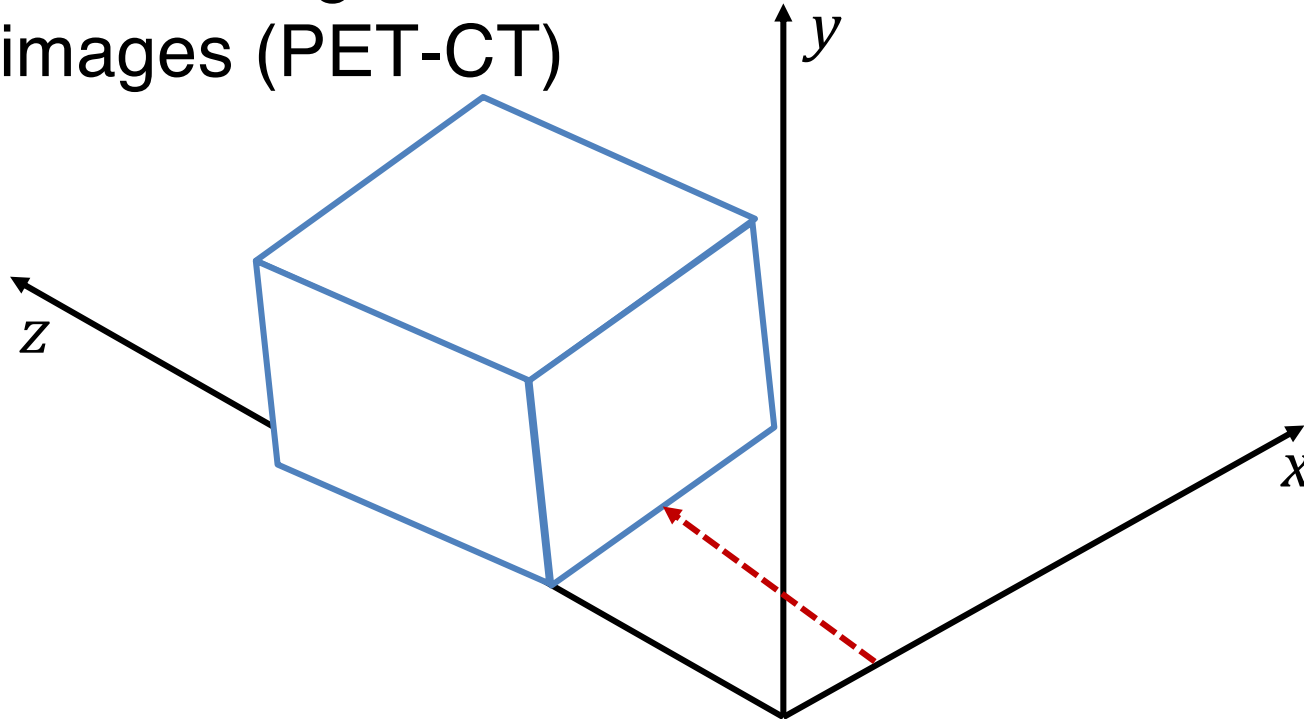
### 1. Movements among different series DICOM coordinates registered images (PET-CT)

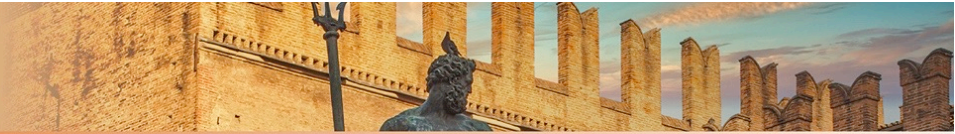




## Image registration problems: geometry inconsistencies

### 1. Movements among different series DICOM coordinates registered images (PET-CT)

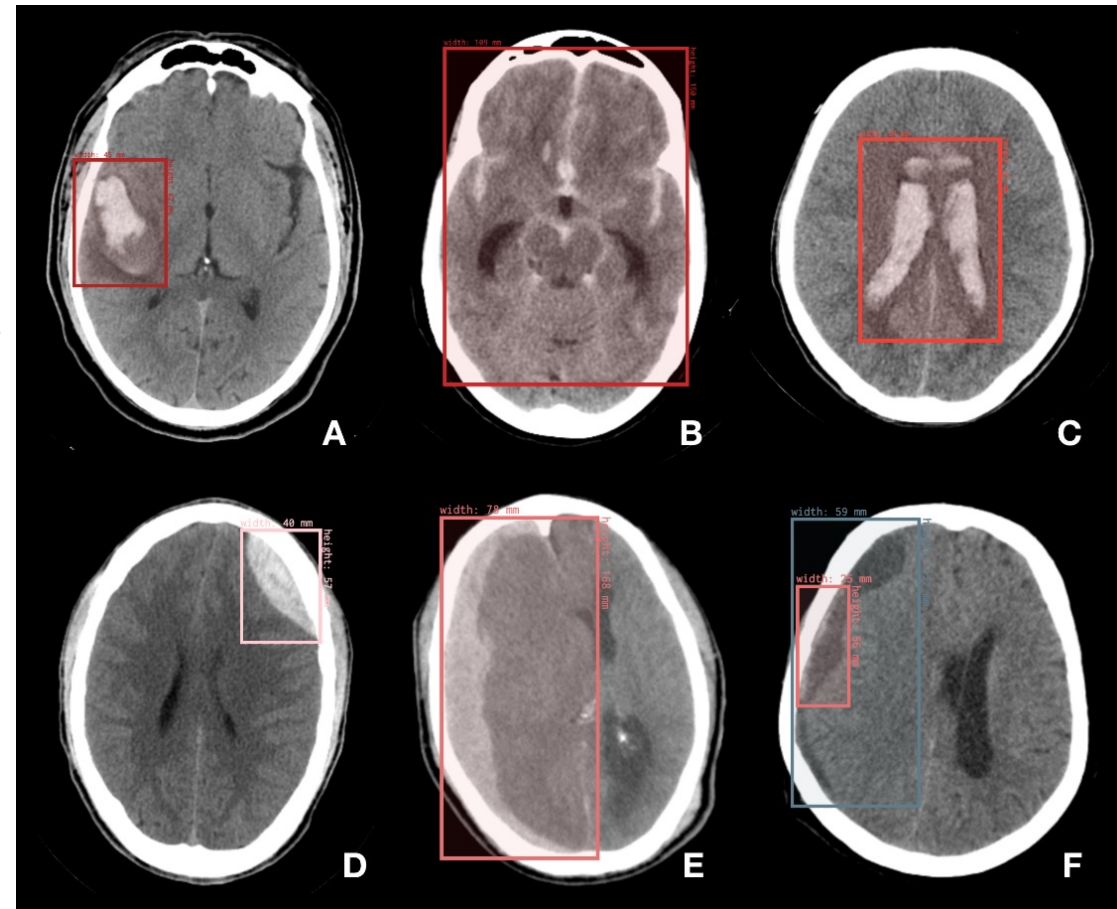




## Image registration problems: choosing the correct boundaries

User bounding box selection for  
 meaningful part of image series

Reis, E. P., Nascimento, F., Aranha, M., Mainetti Secol, F., Machado, B., Felix, M., Stein, A., & Amaro, E. (2020). Brain Hemorrhage Extended (BHX): Bounding box extrapolation from thick to thin slice CT images (version 1.1). PhysioNet.



REGISTRATION

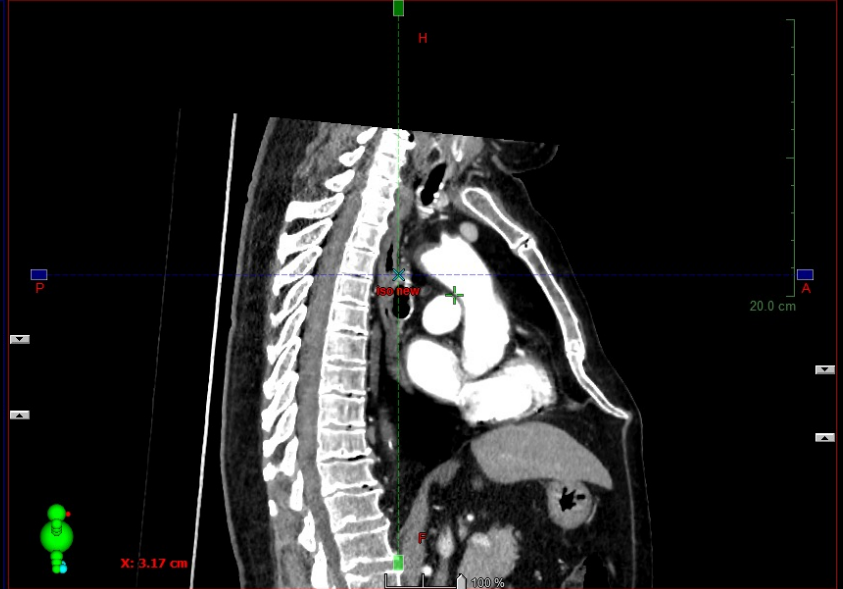
CT Image CT Image  
 CT\_RP\_Ave Arteriosa  
 24/05/2019 30/04/2019

CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT
CT_RP_00	CT_RP_10	CT_RP_20	CT_RP_30	CT_RP_40	CT_RP_50	CT_RP_60	CT_RP_70	CT_RP_80	CT_RP_90	CT_RP_Mip	CT_RP_Min	CT_RP_Ave		
24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019		

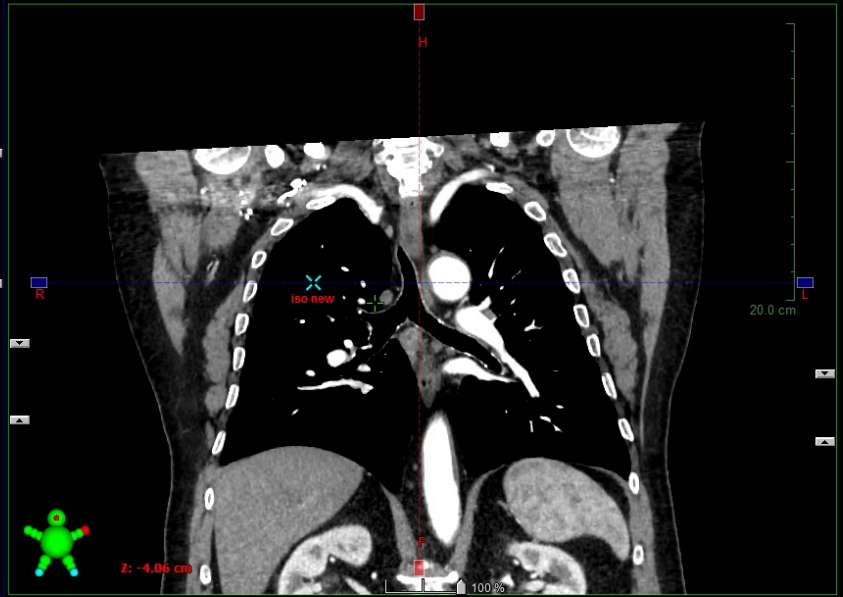
- CT\_RP\_Ave
- Arteriosa
- BODY
- BODY
- Body DVH
- Bones
- ChestWall
- CouchIn...
- CouchSu...
- CTV
- Esophagus
- Heart
- LeftInne...
- LeftOut...
- Lung\_L
- Lung\_R
- Lungs
- PTV
- PTV LSD
- Ribs
- RightInn...
- RightOut...
- Skin
- SpinalCanal
- SpinalCa...
- Reference P...
- iso new
- User Origin



Simulatore Virtuale, HFS  
 Y: 1.52 cm



Frontal - CT\_RP\_Ave - Arteriosa - 30/04/2019 17.24



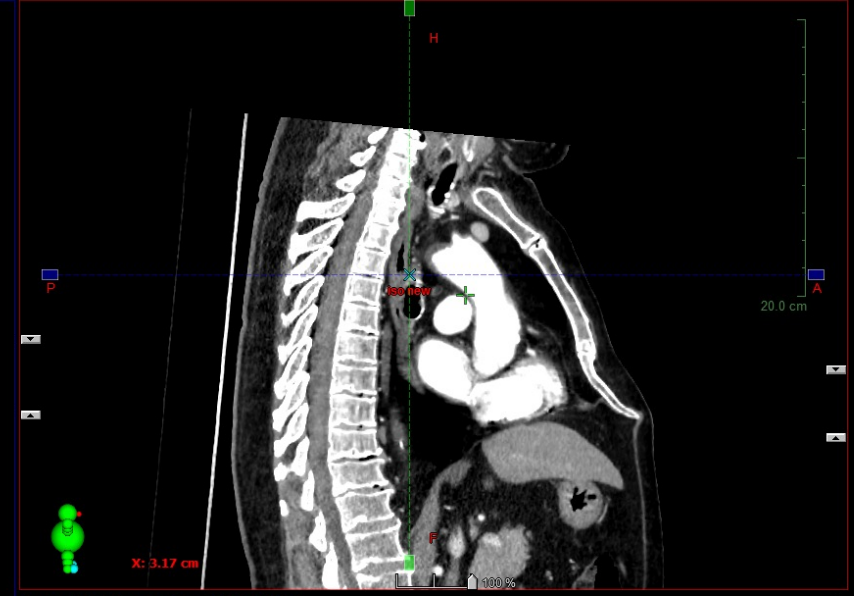
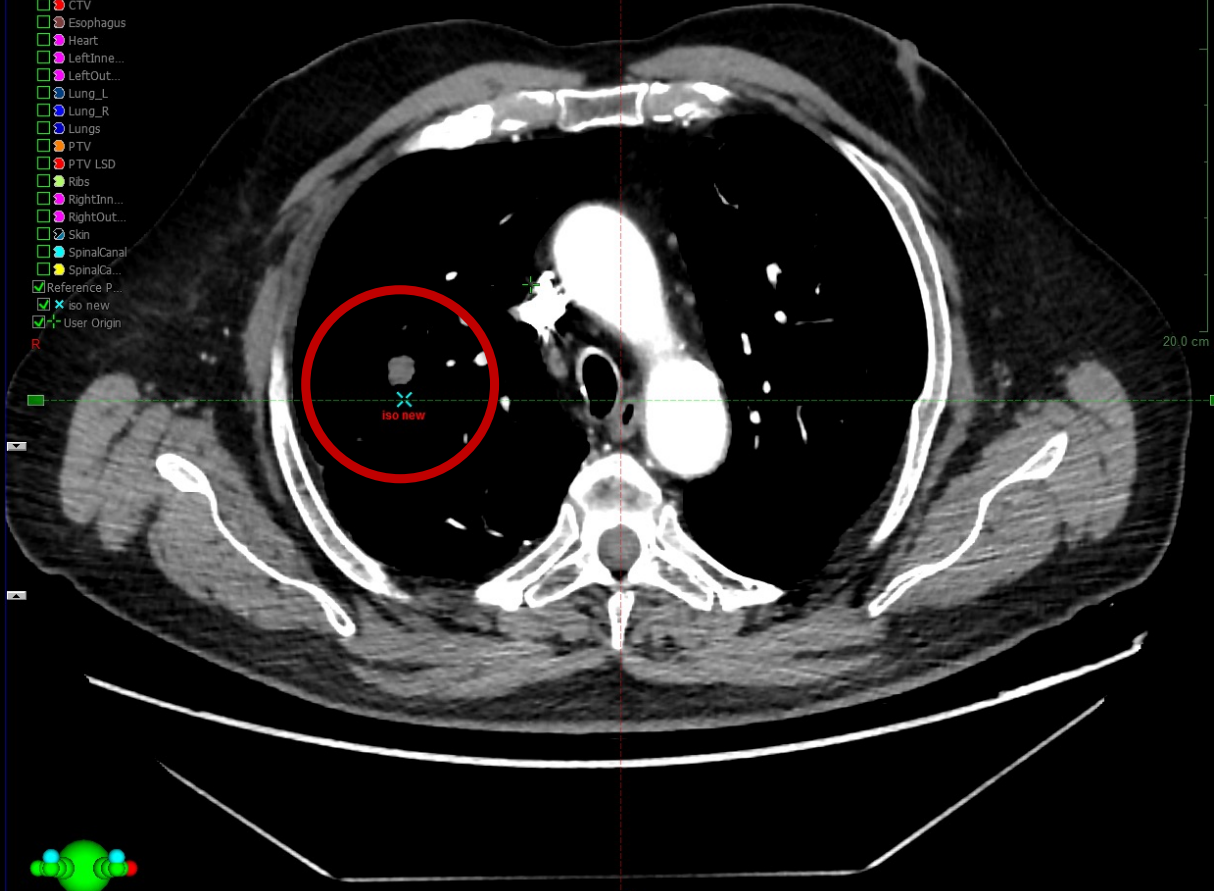
Z: -4.06 cm

REGISTRATION

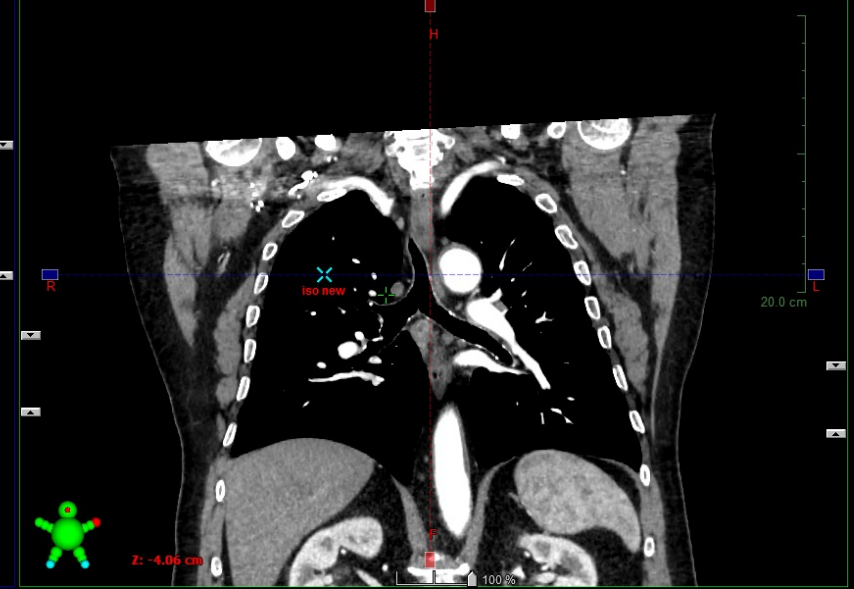
CT Image CT Image  
 CT\_RP\_Ave Arteriosa  
 24/05/2019 30/04/2019

CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT
CT_RP_00	CT_RP_10	CT_RP_20	CT_RP_30	CT_RP_40	CT_RP_50	CT_RP_60	CT_RP_70	CT_RP_80	CT_RP_90	CT_RP_Mip	CT_RP_Min	CT_RP_Ave		
24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019	24/05/2019		

- CT\_RP\_Ave
- Arteriosa
- BODY
- BODY
- Body DVH
- Bones
- ChestWall
- CouchIn...
- CouchSu...
- CTV
- Esophagus
- Heart
- LeftInne...
- LeftOut...
- Lung\_L
- Lung\_R
- Lungs
- PTV
- PTV LSD
- Ribs
- RightInn...
- RightOut...
- Skin
- SpinalCanal
- SpinalCa...
- Reference P...
- iso new
- User Origin



Frontal - CT\_RP\_Ave - Arteriosa - 30/04/2019 17.24



Simulatore Virtuale, HFS  
Y: 1.52 cm

100%

100%

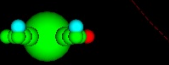
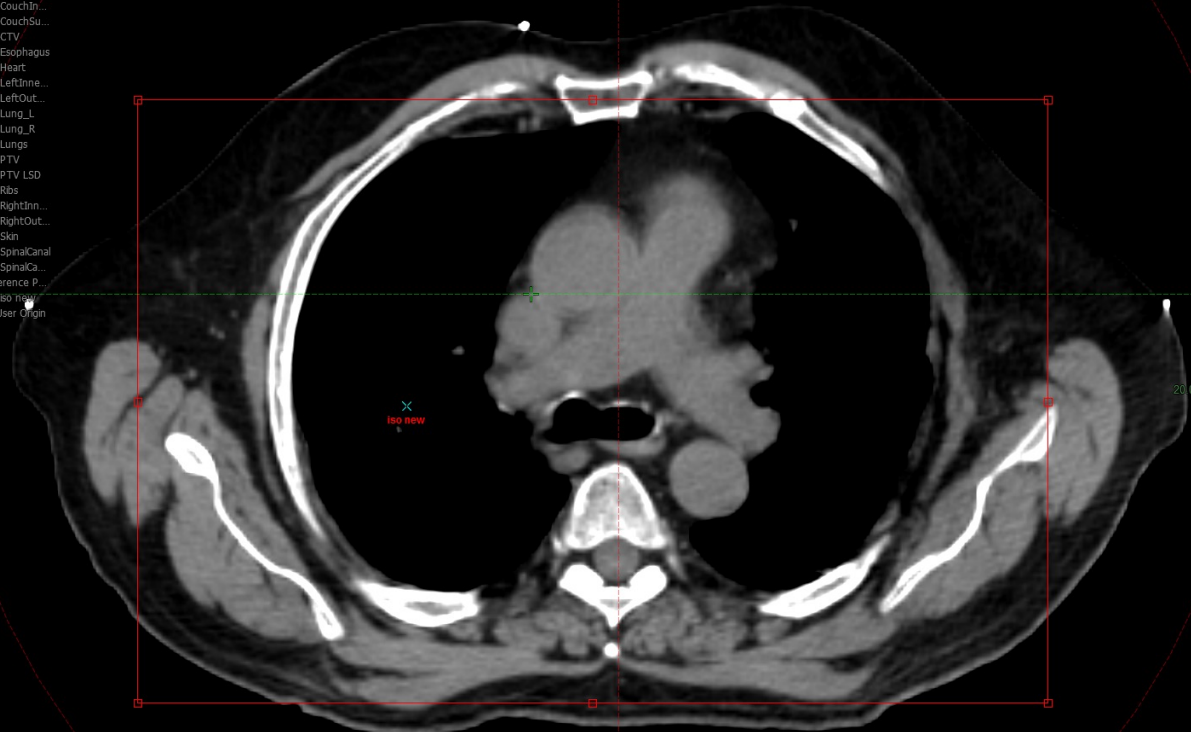
Transversal - CT\_RP\_Ave - Arteriosa - 30/04/2019 17.24

Sagittal - CT\_RP\_Ave - Arteriosa - 30/04/2019 17.24

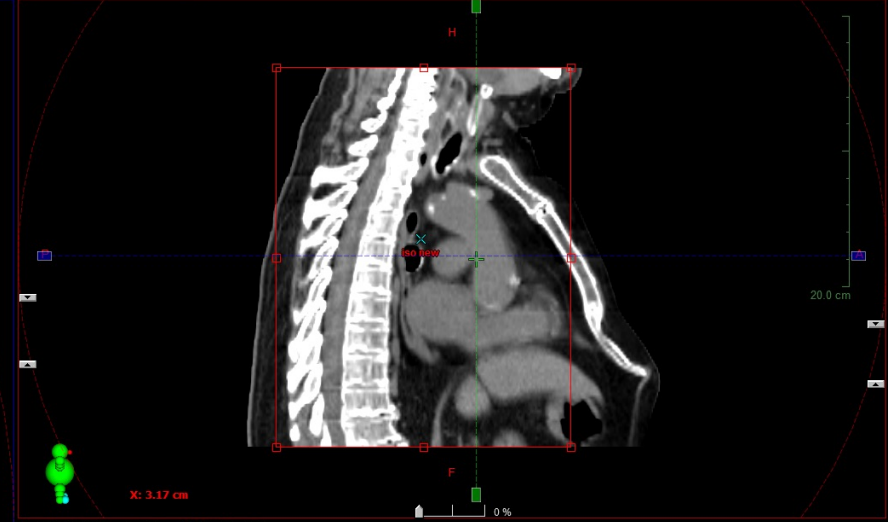
REGISTRATION

CT Image CT_RP_Ave 24/05/2019 Avg	CT Image Arteriosa 30/04/2019	CT RP:00 05/2019	CT RP:10 24/05/2019	CT RP:20 24/05/2019	CT RP:30 24/05/2019	CT RP:40 24/05/2019	CT RP:50 24/05/2019	CT RP:60 24/05/2019	CT RP:70 24/05/2019	CT RP:80 24/05/2019	CT RP:90 24/05/2019	CT RP:Mp 24/05/2019	CT RP:Mn 24/05/2019	CT RP:Ave 24/05/2019	KVCBCT_0 31/05/2019	KVCBCT_0 03/06/2019	KVCBCT_0 05/06/2019
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- CT\_RP\_Ave
- BODY
- Body DVH
- Bones
- ChestWal
- CouchIn...
- CouchSu...
- CTV
- Esophagus
- Heart
- LeftInne...
- LeftOut...
- Lung\_L
- Lung\_R
- Lungs
- PTV
- PTV LSD
- Ribs
- RightInn...
- RightOut...
- Skin
- SpinalCanal
- SpinalCa...
- Reference P...
- Iso new
- User Origin



Simulatore Virtuale, HFS  
Y: 0.28 cm



Frontal - CT\_RP\_Ave - Arteriosa - 30/04/2019 17.24

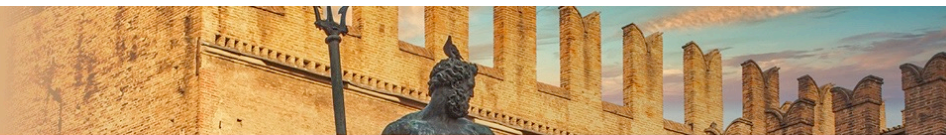


Z: 0.00 cm

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Radioterapia di precisione per un'oncologia innovativa e sostenibile



 Associazione Italiana  
Radioterapia e Oncologia clinica

 Società Italiana di Radiobiologia

 Associazione  
Italiana di  
Radioterapia  
e Oncologia  
clinica

**BOLOGNA, 25-27 NOVEMBRE**  
PALAZZO DEI CONGRESSI