L'Institut Valencià d'Investigació Cooperativa en Física Avançada

organizes ***Friday's miniWorkshops***

Friday mini WORKSHOP **9 nov**

Medical Physics

and some related fields

HOSPITAL LA FE DE VALENCIA

UNIVERSITARI I POLITÈCNIC

Biomarkers for Medical Imaging

Luis Martí-Bonmatí

Luis.Marti@uv.es

Medical Imaging Area

Medical Imaging

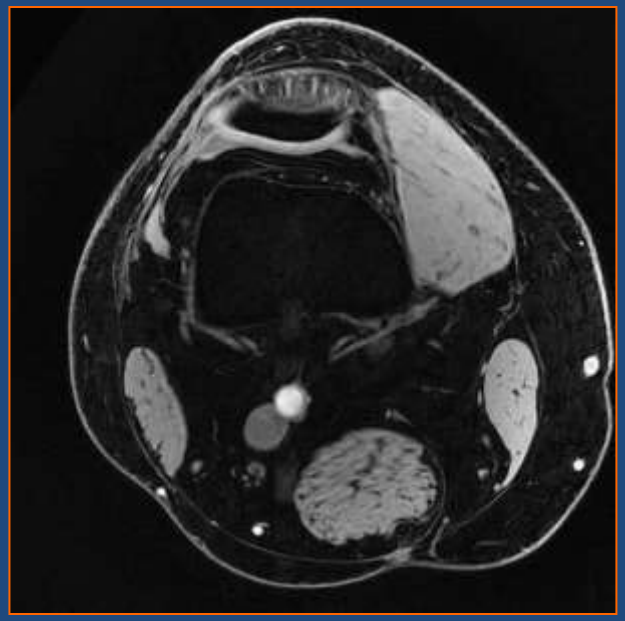
Innovación y experiencia al servicio del paciente

- Medical Imaging is a key tool in diagnosis, treatment monitoring and prediction of therapeutic response of the disease. It is also a fundamental tool for guiding many minimally invasive therapeutic procedures.

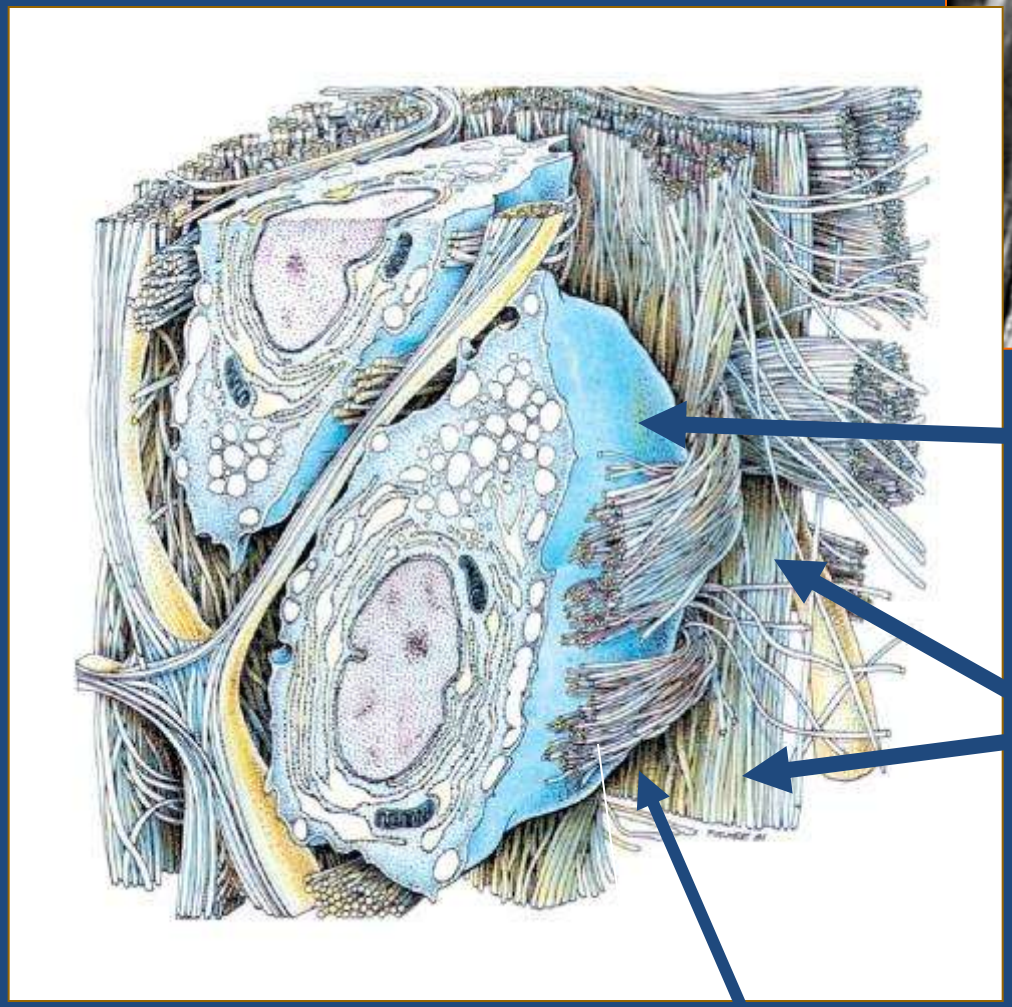
- Traditional radiological diagnosis is based on the integration and qualitative assessment of imaging findings obtained from conventional radiography, ultrasound, CT and MRI.

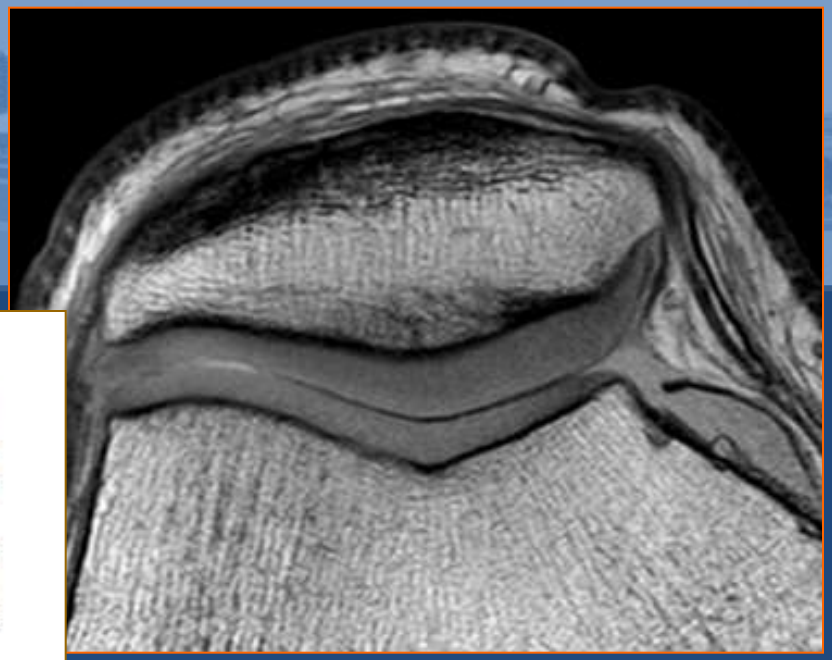
- With the advent of digital environments, images are no longer considered just a final product for the diagnosis but sometimes an intermediate product from which different information, apart from qualitative or visual, can be extracted.

- Technology and engineering have changed the approach to obtain information from medical imaging. The knowledge of the biological basis of the disease has also boosted the use of these new parameters, known as biomarkers.



Joint Cartilage





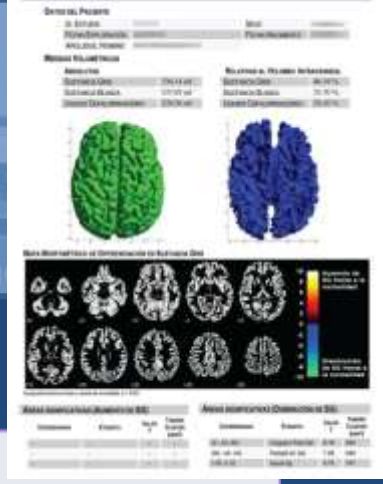
Chondrocytes

Free collagen fibers, proteoglycans and glycosaminoglycans

Structure, Function and Composition

Collagen fibers around the chondrocytes

Learning Objectives



Definition

- To understand what are imaging biomarkers and how can they improve diagnosis and treatment follow-up

Types

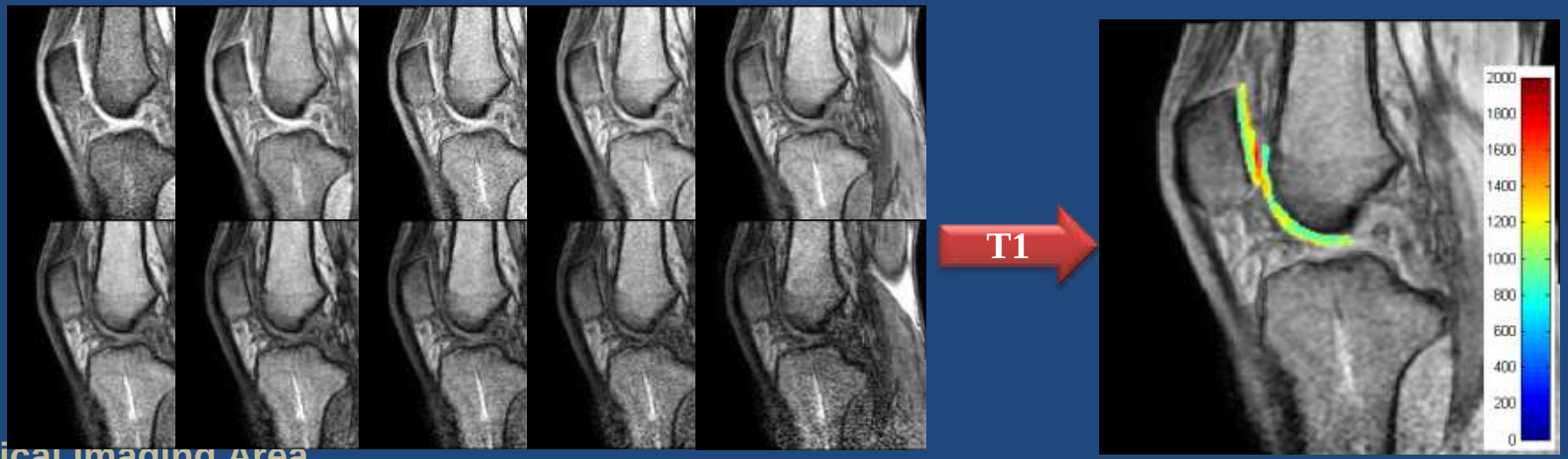
- To describe the different types of biomarkers

Development

- To analyze the process of biomarkers development, including validation, qualification and standardization

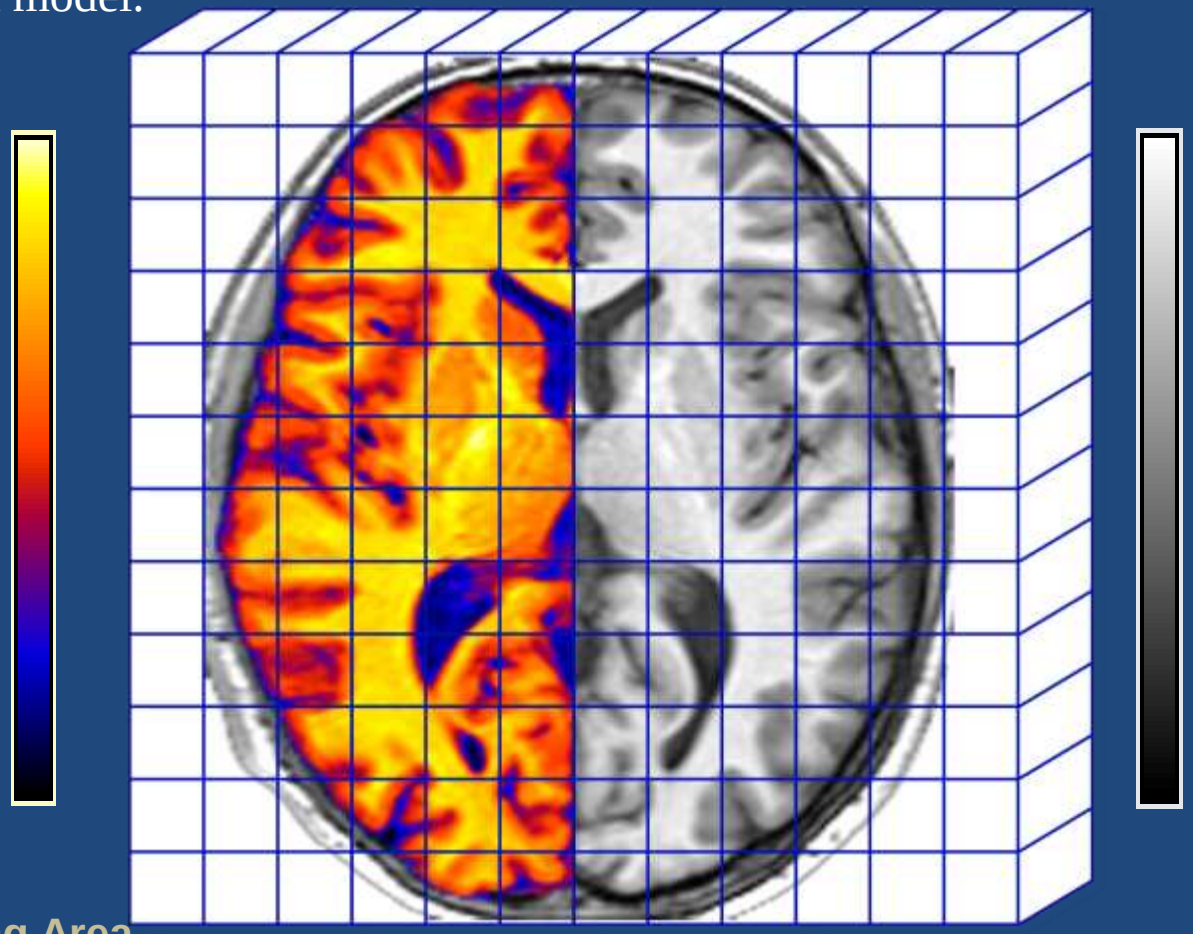
What are biomarkers?

- Any characteristic of a tissue that can be objectively measured and that represents a parameter of its biological, functional or structural organization.
- An imaging biomarker is any parameter obtained with standard and advanced techniques to explode, quantify and represent a tissue specific property.
- These properties are hidden parameters (structural, physiological, functional, cellular, biochemical) that can be extracted after applying to the acquired images different computational models and specific statistical processing.
- The parametric maps represent the spatial distribution in the analysed tissue. In these synthetic images, the pixel signal is proportional to the magnitude of the biomarker or change.



Parametric Image

- Derived secondary images which pixels represent the distribution values of a given parameter (morphological or functional) usually obtained by the numerical adjustment of a mathematical model.



Types of imaging biomarkers: cancer treatment

- Different anatomical, functional and molecular tumour characteristics can be used as imaging biomarkers.
- In cancer treatment, CT and MRI measurements of changes in tumour size are the base of the RECIST (Response Evaluation Criteria in Solid Tumours) criteria.
- RECIST-based markers are unable to depict early tumor response.
- RECIST-based markers are suboptimal to assess the effect of some targeted treatments that do not cause regression of tumour volume, but rather increase in the extent of tumour necrosis.

Types of imaging biomarkers: cancer treatment

- Functional biomarkers obtained with several imaging methods have the potential to complement or even replace the RECIST criteria (tumour perfusion, oxygen level, glucose metabolism).
- Relative to molecular biomarkers, which are target-specific, functional biomarkers have the advantage of probing general capabilities of disease, such as cell death, proliferation, glycolysis, hypoxia, tumour invasiveness, angiogenesis, lymphangiogenesis, inflammation and fibrosis.
- Important efforts of qualification and standardization remain to be done before the acceptance of some of these functional biomarkers as surrogate endpoints.

Types of imaging biomarkers

- **Prognostic biomarkers:** those that **a**ffect the outcome of patients in terms of a clinical endpoint.
- **Predictive biomarkers**: which affect the effect of a specific treatment on a clinical endpoint.
- **Surrogate biomarkers**: those measurements which may replace a clinical endpoint in clinical trials carried out to evaluate the effect of a specific treatment.

Biomarkers and Medical Imaging

Innovación y experiencia al servicio del paciente

Define a clinical and therapeutic target for a disease: prediction, detection, staging, grading or therapeutic response

Is it possible to develop an imaging biomarker that can solve the problem?

Define a study that can be used as a proof of principle and validation of the biomarker

Are the results satisfactory in terms of sensitivity / specificity / utility?

Is it robust and reproducible?

Innovation and clinical application

Can it be improved?

Biological and clinical knowledge

Technical and methodological knowledge

Statistical knowledge

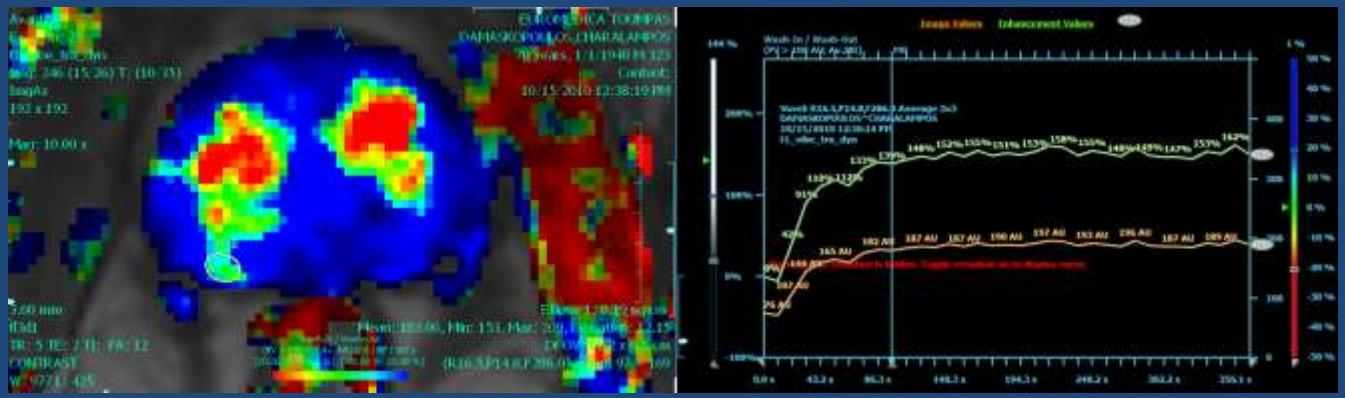
Technical advances

The Ideal Biomarker

- Must be clinically useful, allowing a measurable clinical improvement.
- Must (usually indirect or substitute) measure the target process adequately.
- Must be standardized in terms of image acquisition (technical parameters), image preparation, image processing and data measurement.
- Must have a high sensitivity to correctly classify as abnormal a true altered finding.
- Must have a high specificity to correctly identify healthy people as negative or not having the condition.

The Ideal Biomarker

- Must be reproducible to replicate the obtained value, so that it remains lower than the intended differences, obtaining similar results in different equipments.
- Must be obtained at the lowest possible costs (low-priced) and in the shortest time (fast).
- Must be safe and harmless to the patient.
- Must have the potential to become a "clinical endpoint" or a "virtual biopsy".



The Ideal Biomarker

Sensitivity

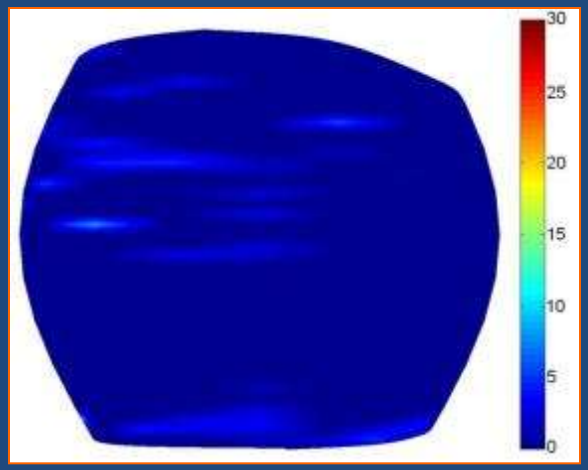
Specificity

Reproducibility

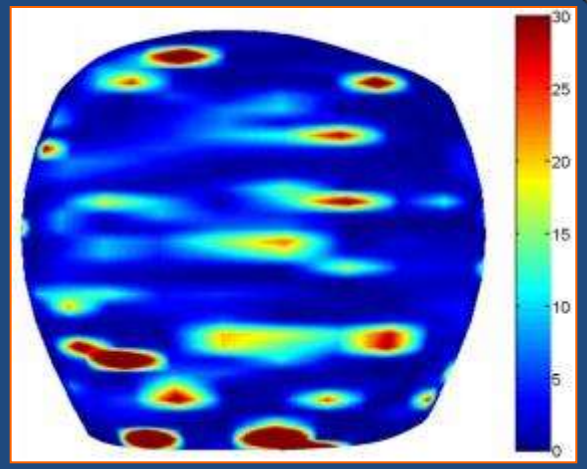
Clinical validity

Standardization

Cost



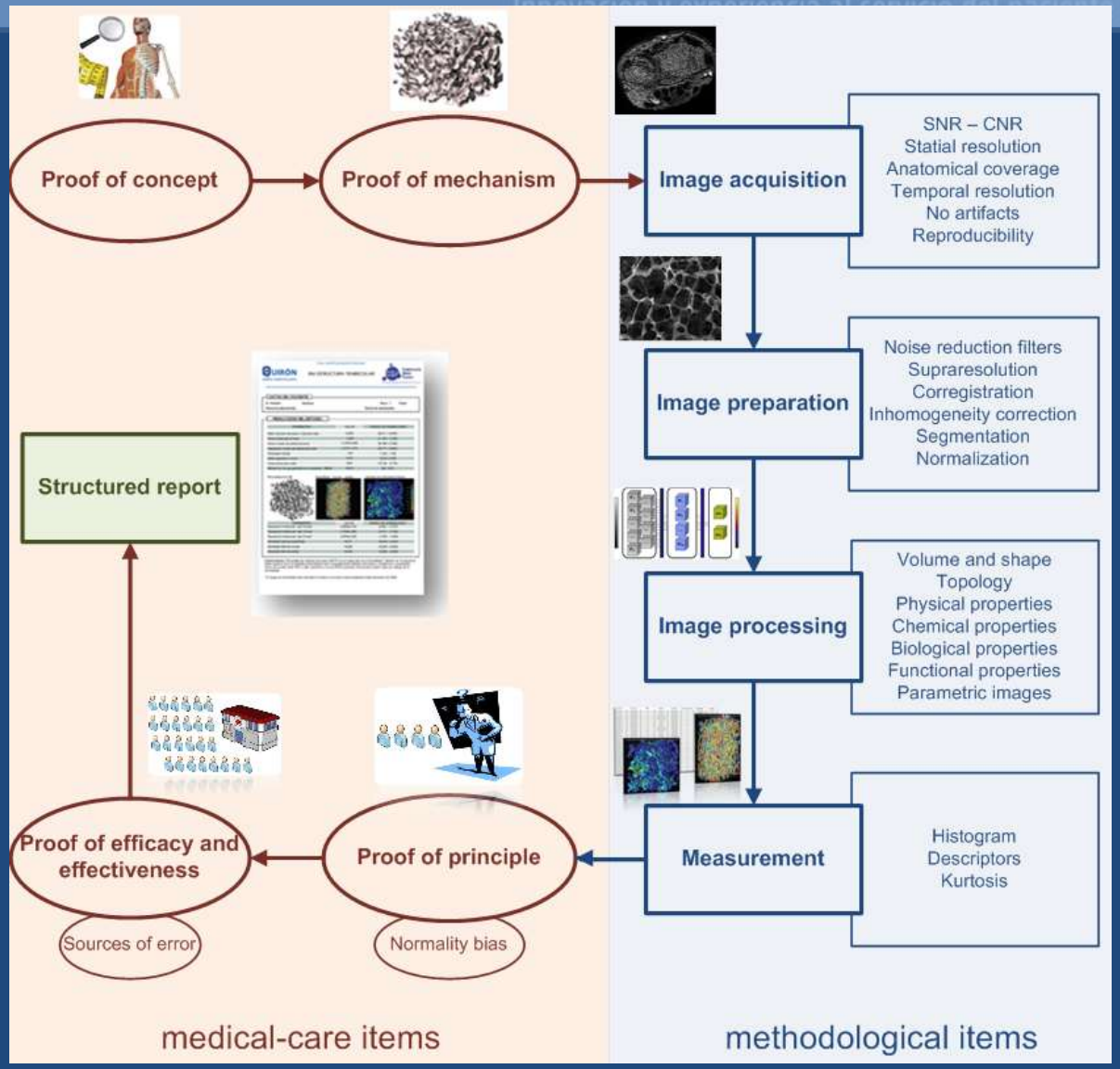
Normal



Initial Chondropathy

Steps for the Development and Integration

- The process required to integrate an imaging biomarker into both clinical practice and clinical trials is complex and must meet the criteria of conceptual consistency, technical reproducibility, sensitivity and specificity.
- The innovation path to biomarker development, expansion and subsequent implementation involves a number of consecutive steps .



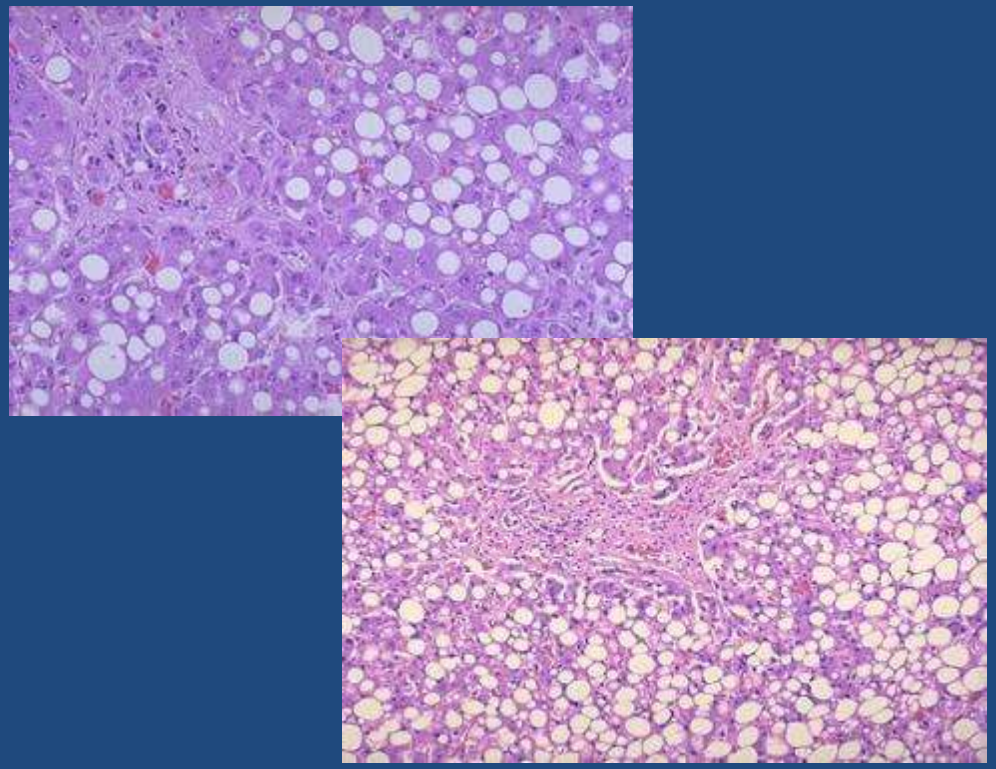
Initial Development of Biomarkers

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurements → Proof of principle → Proof of efficacy and effectiveness → Structured report

Proof of Concept

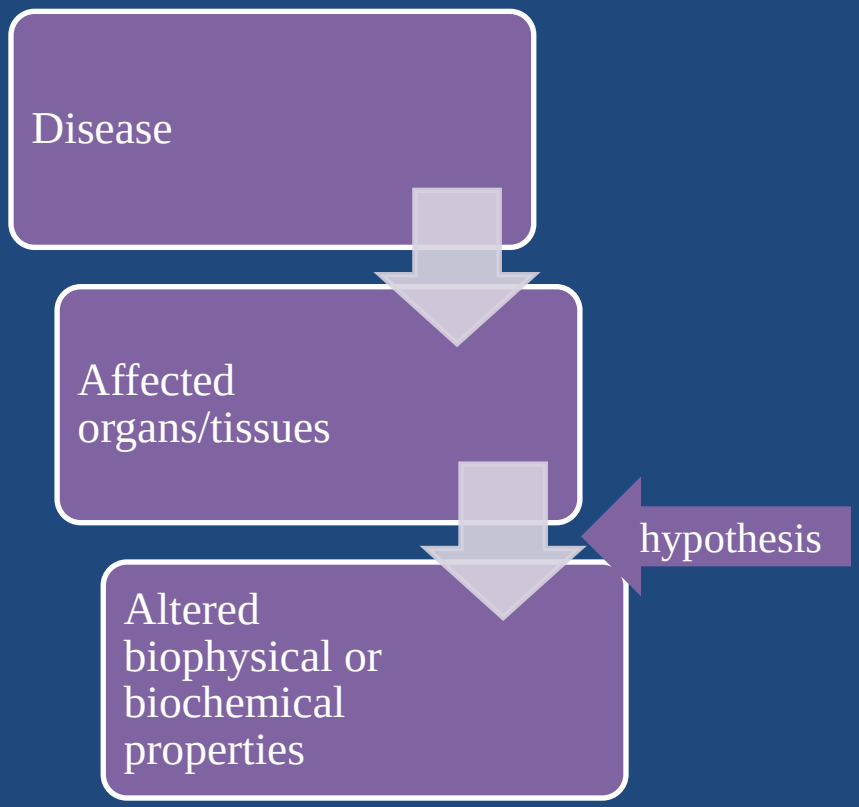
Define the reasons why a specific aspect of the disease has to be measured.

Demonstrate that a specific biological process, seen as a cause and effect chain, may be studied using the available imaging and computational techniques.



Initial Development of Biomarkers: Cartilage

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurements → Proof of principle → Proof of efficacy and effectiveness → Structured report



Concept

- The joint cartilage is initially resistant to vascular invasion from the subchondral bone
- As the joint cartilage degenerates, there is a change with overexpression of the vascular endothelial growth factor (VEGF). This angiogenesis signaling protein is strongly expressed
- New vessels and capillaries are formed

Mechanism

- Imaging biomarkers of neovascularization may be used to evaluate initial degeneration, progression of degeneration and vascular response to treatment

Initial Development of Biomarkers: Brain

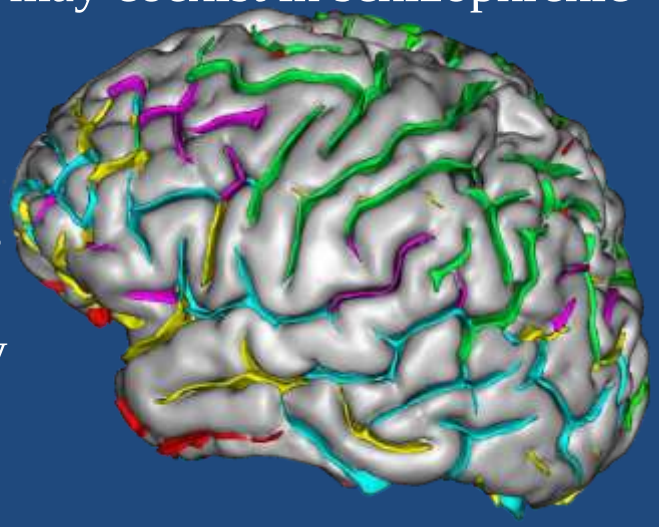
Proof of Concept

Several morphometric and functional abnormalities have been reported in patients suffering from psychiatric and neurodegenerative disorders. Neurobiological mechanisms are difficult to understand by interpreting functional and structural data separately.

Both functional and neuronal density abnormalities may coexist in schizophrenic patients in specific regions.

Mechanism

If proven, these functional abnormalities coexisting with focal brain reductions in patients with neurodegenerative and psychiatric disorders may have both grading and therapeutic interest.



Initial Development of Biomarkers: Liver

Innovación y experiencia al servicio del paciente

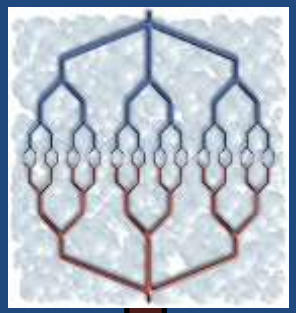
Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurements → Proof of principle → Proof of efficacy and effectiveness → Structured report

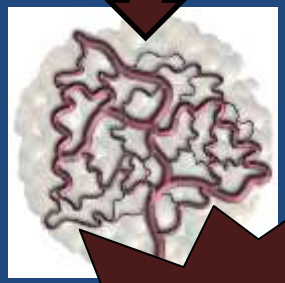
Liver tumors → ↑ Energetic demands

↑ Blood (oxygen + nutrients)

Angiogenesis and neovascularization

–Flow
– Volume
– Disorder
– VEGF





Diagnostic markers

Radiology 2009;251:317-35
J Natl Cancer Inst 2005;97:172-87

Angiogenesis and neovascularization ↔ VEGF production

Angiogenesis assessment: complex and expensive

1. Microvascular density (MVD)
2. Determination of intratumoral VEGF
3. Monitoring vascular permeability

Can we use DCE-MR imaging to model angiogenesis?

Quantitative parameters obtained from the pharmacokinetic modeling of DCE-MR images

Disease assessment

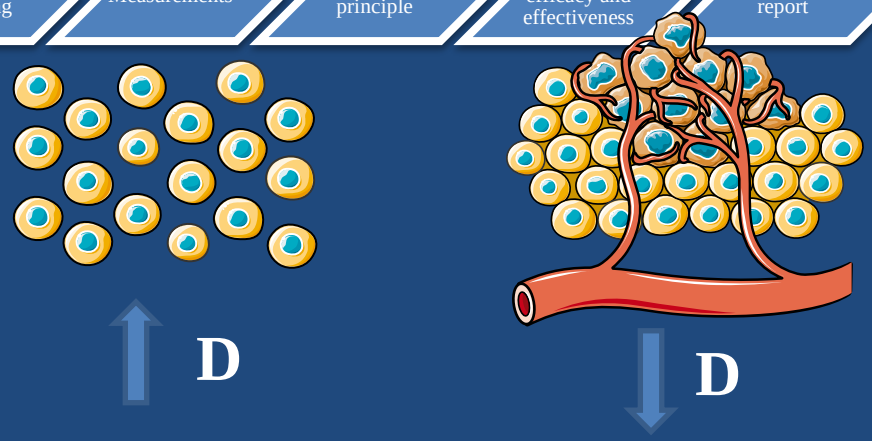
Treatment evaluation

Ferrara. Endocr Rev 2004;25:581-611

Initial Development of Biomarkers: Prostate

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurements → Proof of principle → Proof of efficacy and effectiveness → Structured report

- There is a relationship between pathological alterations (cell density, interstitial space and angiogenesis) and water molecules diffusion.
- *In vivo* quantification of the diffusion properties of water molecules in biological tissues should provide information about cellularity and microstructural organization.
- Diffusion coefficients are elevated in structures with a reduced cell density and increased interstitial space.

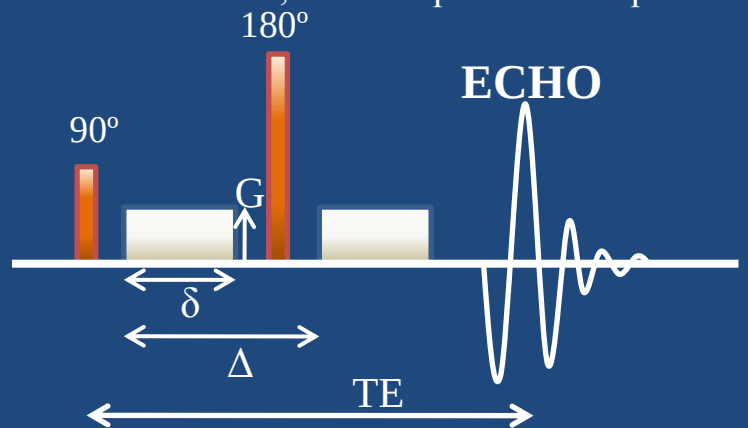


- Water molecules behavior in tissues can be quantified by MR imaging from the capacity of the proton spin to rephase after the application of two symmetrical field gradients.
- The purpose of DW-MR sequence is to estimate the diffusion coefficient of water molecules in tissues.
- The sensitivity to diffusion can be controlled by means of the so called 'b value', which depends on the pulses characteristics:

$$b = \gamma^2 \cdot G^2 \cdot \delta^2 \cdot \left(\Delta - \frac{\delta}{3}\right)$$

[s/mm^2]

Gyromagnetic constant — Gradient strength — Gradient duration — Gradient separation

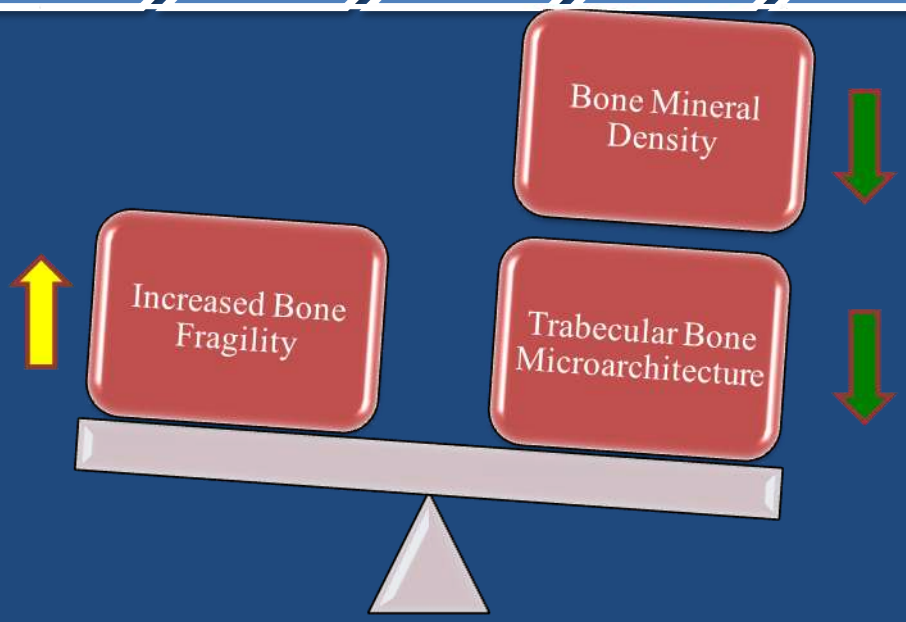


Initial Development of Biomarkers: Bone

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurements → Proof of principle → Proof of efficacy and effectiveness → Structured report

From a certain age and a negative skeletal balance, bone involution determines a bone mass reduction.

In osteoporosis, trabecular structure maintains its shape while beams become thinner augmenting inter-trabecular spacing, resulting in a more porous structure and a reduction of whole bone quantity.



Bone mass loss
↓
Decrease density
↓
Dual Energy X-Ray Absorptiometry (DEXA)

Microarchitecture deterioration
↓
Mechanical and structural parameters
↓
MRI Image processing

Initial Development of Biomarkers

Innovación y experiencia al servicio del paciente

Proof of concept | **Proof of mechanism** | Image acquisition | Image preparation | Image processing | Measurement | Proof of principle | Proof of efficacy and effectiveness | Structured report

Proof of Mechanism

Demonstrate the interrelationship between the biomarker and the concept, focusing on the effect (in magnitude and direction) that a specific disease or a treatment have on the biomarker.

Acquisition and analysis of Biomarkers

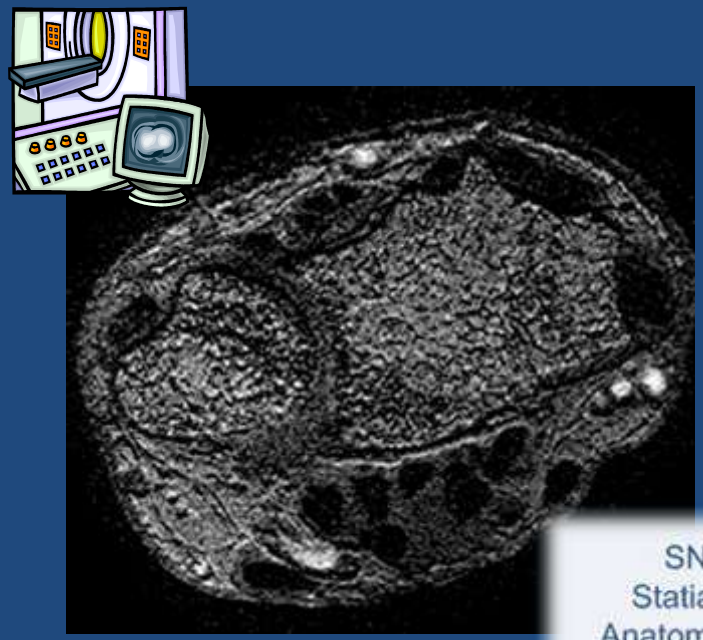
Innovación y experiencia al servicio del paciente

Proof of concept | Proof of mechanism | **Image acquisition** | Image preparation | Image processing | Measurement | Proof of principle | Proof of efficacy and effectiveness | Structured report

Image Acquisition

Appropriate images are essential for the extraction of useful biomarkers.

Irrespective of the technique used (radiography, ultrasound, CT, MRI, SPECT or PET), several issues must be taken into consideration.



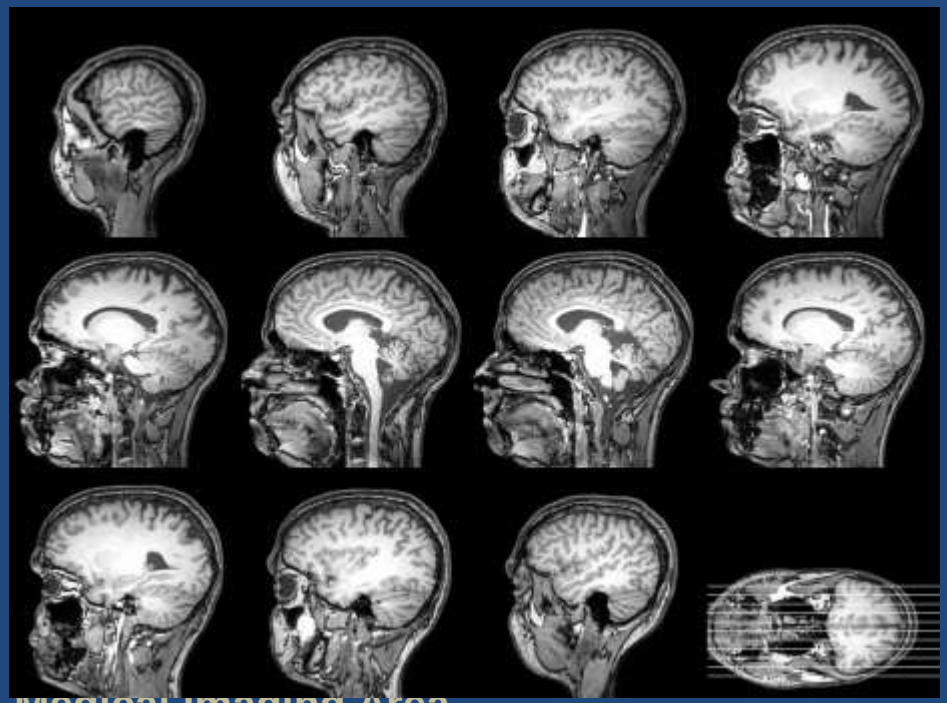
SNR – CNR
Statial resolution
Anatomical coverage
Temporal resolution
No artifacts
Reproducibility

Acquisition and analysis of Biomarkers: Brain

Proof of concept → Proof of mechanism → **Image acquisition** → Image preparation → Image processing → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

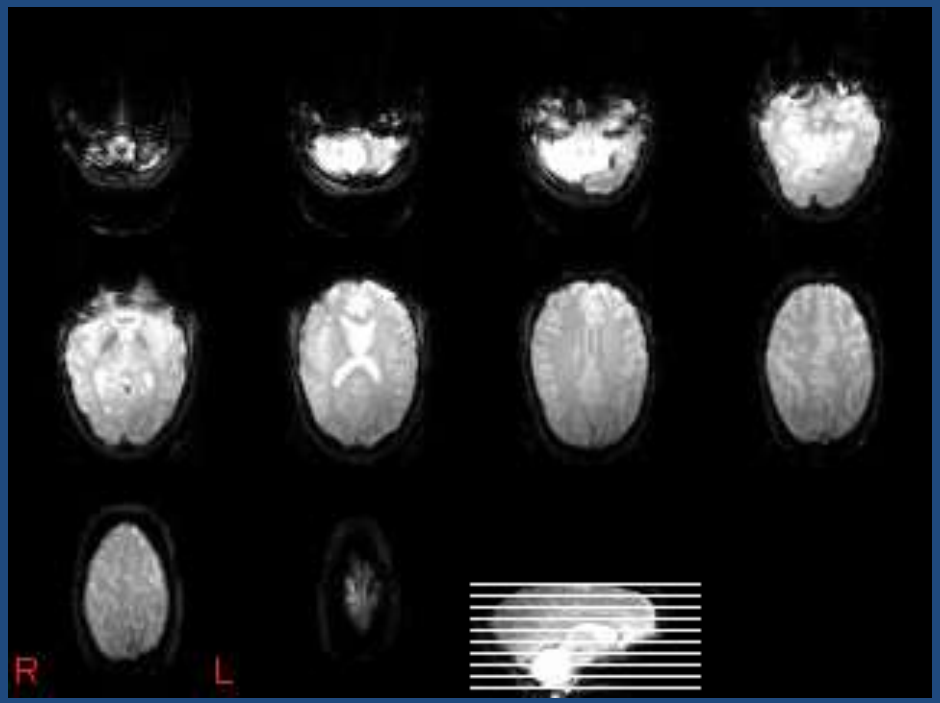
T1W-GRE 3D High Resolution morphometric analysis

TE / TR: 3.9 / 8.3 FA: 8º
Orientation: Sagittal; Matrix: 256 x 256
Slices: 160; Voxel: 0.94x0.94x1; Gap: 0
Acquisition time: 5:20’



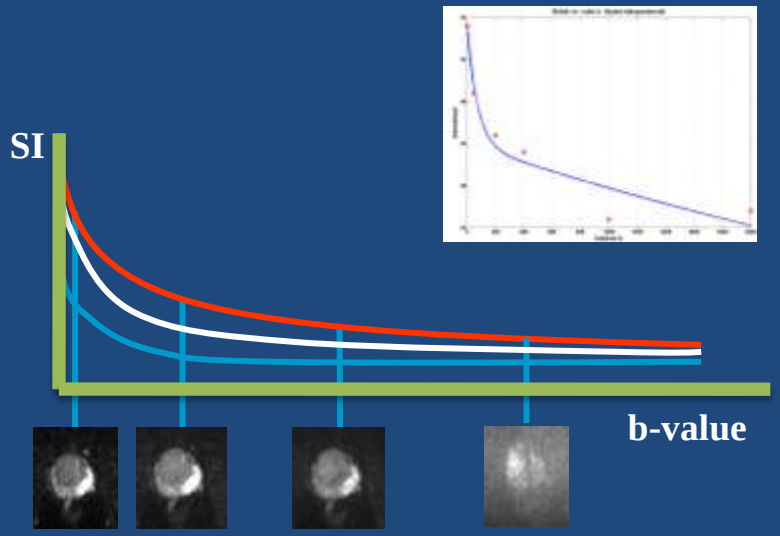
EPI T2* for functional MR evaluation

TE / TR: 19 / 2275 FA: 90º
Orientation: Axial; Matrix: 80 x 80; Slices: 48
Voxel: 2.88x2.88x2.60; Gap: 0
Acquisition time: 2’; Dynamics: 80



Acquisition and analysis of Biomarkers: Prostate

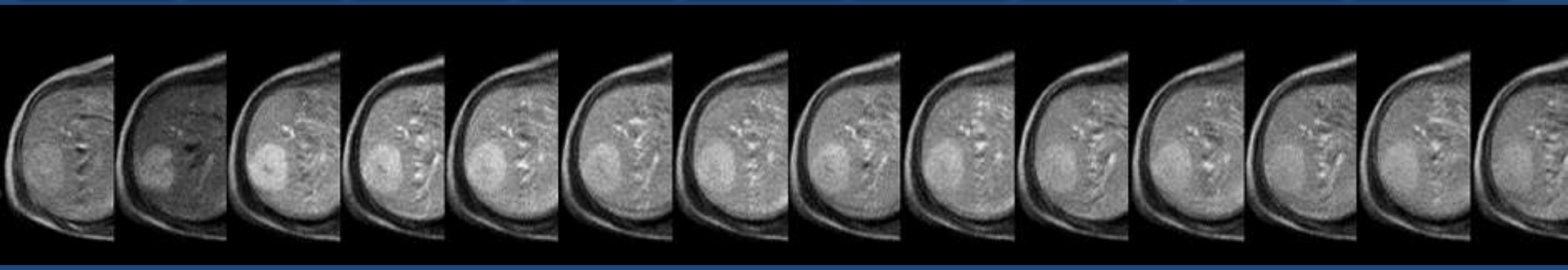
- DWI: MR signal decays while the b-value increase.
- Using different b-values, an estimation of the diffusion coefficient can be obtained from the fitting and modeling of the signal decay.
- These models can be based on either a monoexponential or biexponential modelling of the MR signal decay.
  - Monoexponential: Non standardized.
  - Bi-exponential: Calculation of fast and slow components (D, D*) with the IVIM theory.



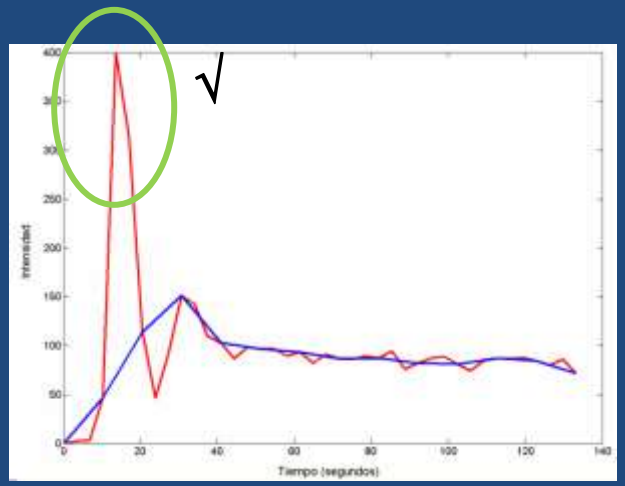
General recommended guidelines:

- Excellent SNR provided by SE-EPI sequences. Parallel imaging techniques to reduce EPI factor. Spectral fat suppression (SPIR, SPAIR) combined with gradient reversal to avoid fat overlapping artifacts. Respiratory synchronization. VCG synchronization in cardiac DWI.
- Acquisition of multiple b-values to be specified by the Cramer-Rao lower bound theory

Acquisition and analysis of Biomarkers: Liver

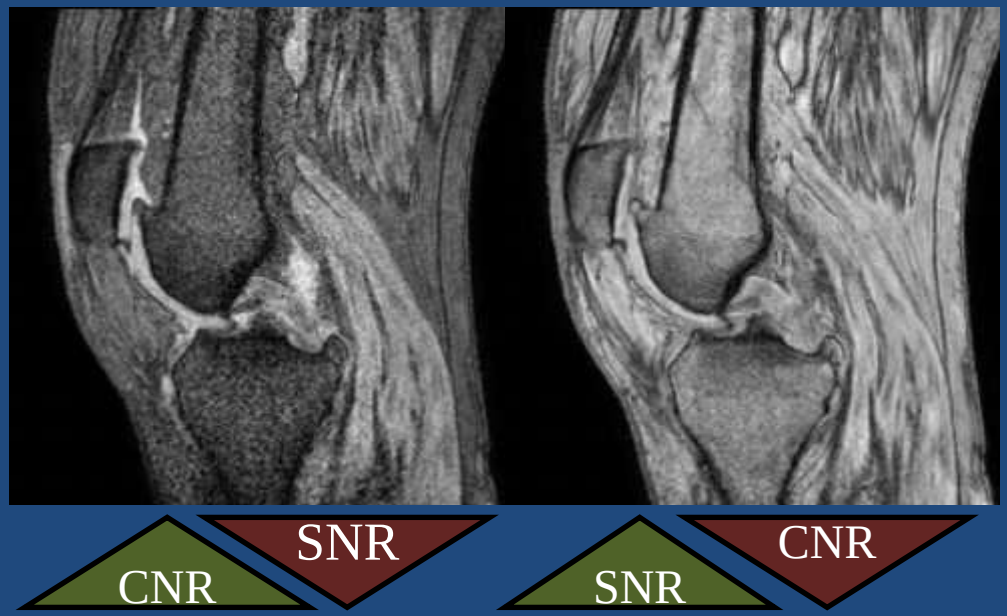


- Spatial resolution with whole anatomical coverage (24 slices)
- In-plane resolution (1.5x1.5 mm)
- Slice thickness (7 mm)
- Temporal resolution: 40 dynamics, 3.7 s each



Acquisition and analysis of Biomarkers: Cartilage

Proof of concept → Proof of mechanism → **Image acquisition** → Image preparation → Image processing → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

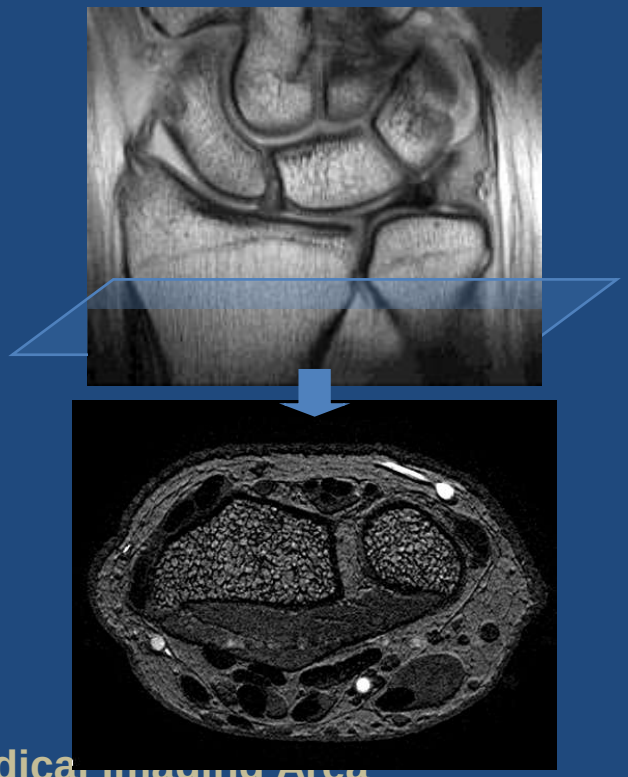


Signal to Noise vs. Contrast to Noise ratio (SNR and CNR)

- Perfusion PKM
- Spatial resolution with whole anatomical coverage (10 slices)
- In-plane resolution (0.78x0.78), slice thickness (7 mm)
- Temporal resolution and Sampling rate: 80 dynamics, 2.7 s each
- Acquisition of multiple images at different echo times to optimized contrast and signal.

Acquisition and analysis of Biomarkers: Bone

- Trabecular Bone Structure: Field Strength of 3 Tesla
- High spatial resolution: 180 μm^3 (isotropic)
- T1-weighted Gradient Echo, FA=25º, TE=5ms, TR=16ms
- 60 axial slices



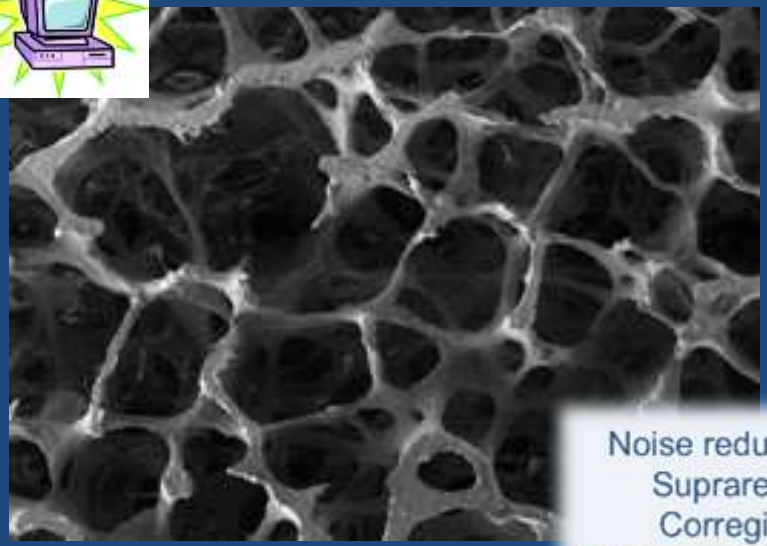
Acquisition and analysis of Biomarkers

Innovación y experiencia al servicio del paciente

Proof of concept → Proof of mechanism → Image acquisition → **Image preparation** → Image processing → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

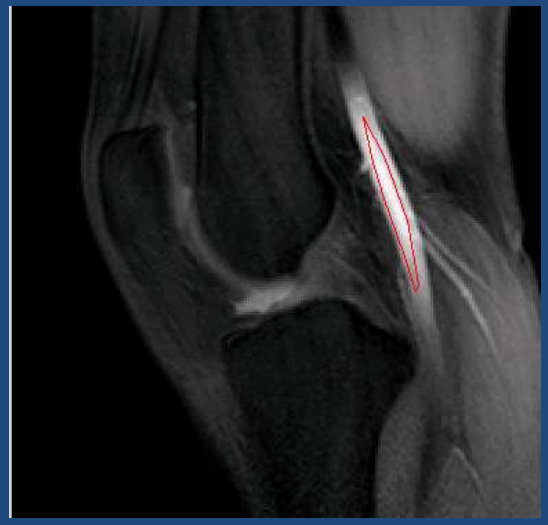
Image Preparation

Prior to the analysis and modeling of the signals, images must be processed making sure that the acquired data are optimal for the analysis.

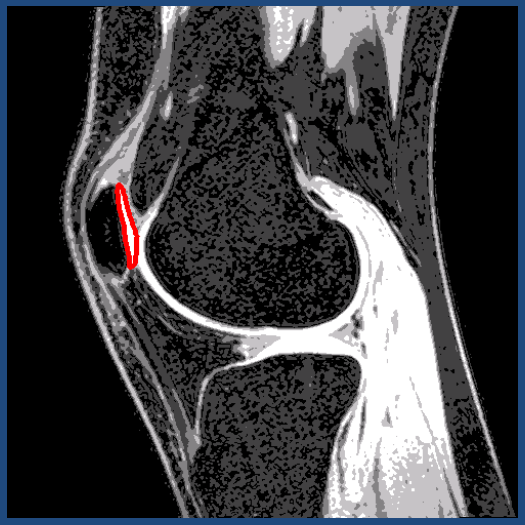


Noise reduction filters
Supraresolution
Corregistration
Inhomogeneity correction
Segmentation
Normalization

Acquisition and analysis of Biomarkers: Cartilage



Arterial input function (popliteal artery)



Patellar cartilage segmentation

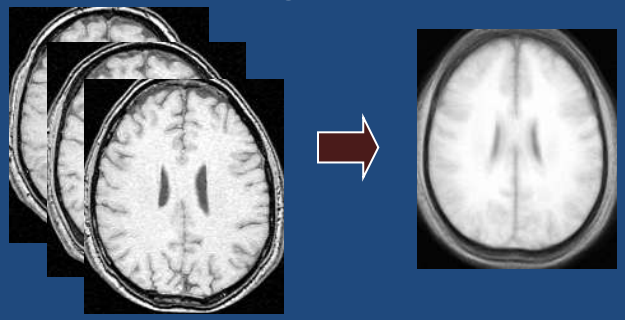
Femoral cartilage segmentation

Acquisition and analysis of Biomarkers: Brain

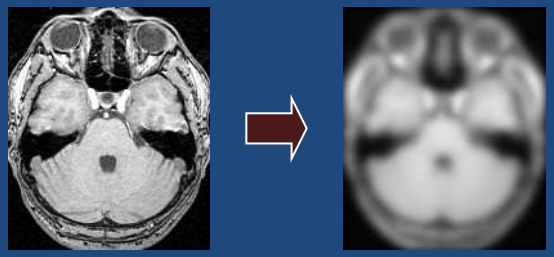
Proof of concept → Proof of mechanism → Image acquisition → **Image preparation** → Image processing → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

Normalization and registration

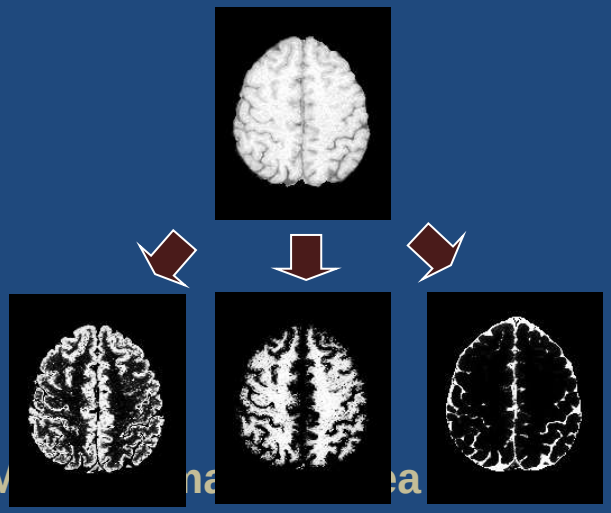
Average filter



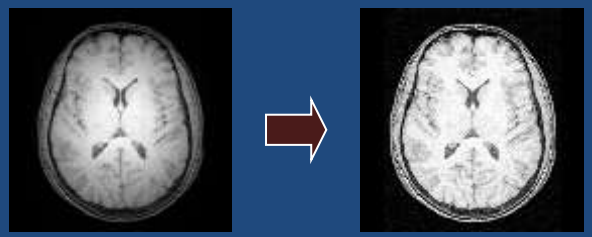
Smoothing filter



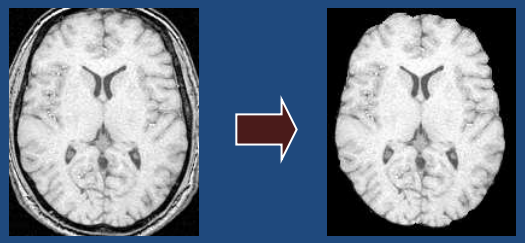
Segmentation



Bias inhomogeneity noise correction



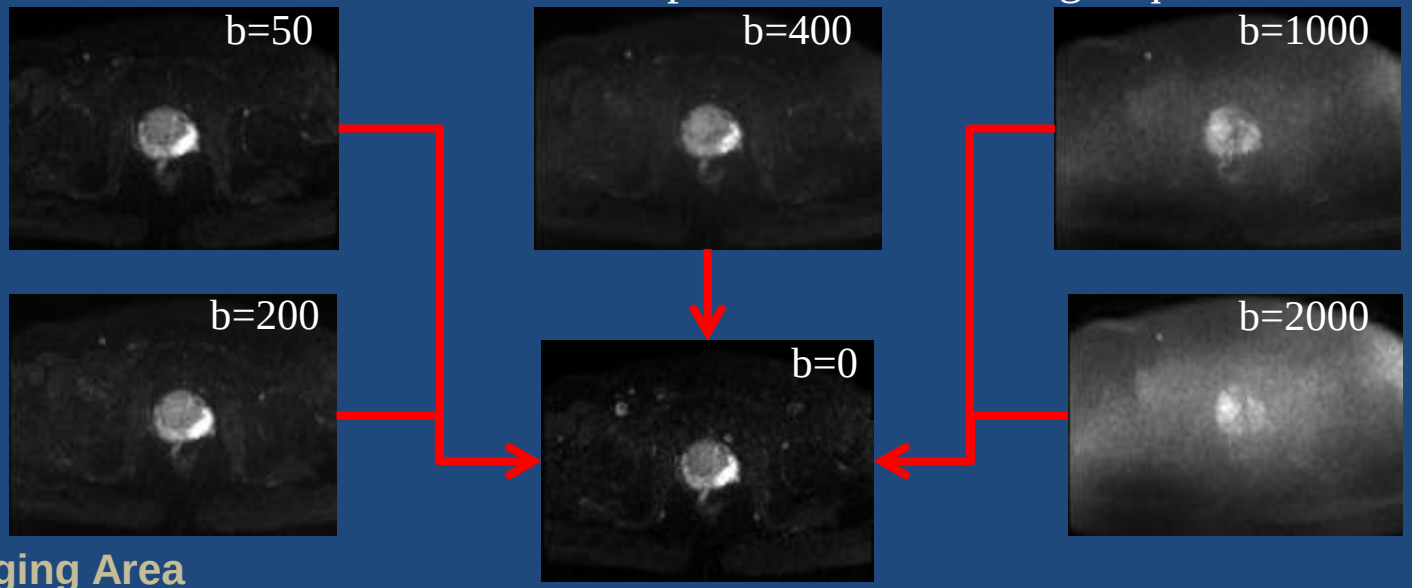
Extract brain tissue



Acquisition and analysis of Biomarkers: Prostate

Image registration through all the b-values of the study

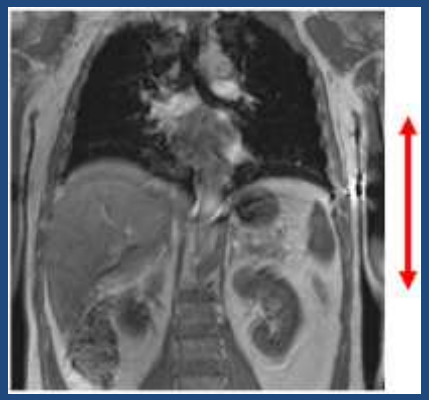
- SPM-based
- Reference: b=0
- Minimize apparent displacements produced by the Eddy currents effect through the b-values
- Minimize localization errors due to patient motion during acquisition

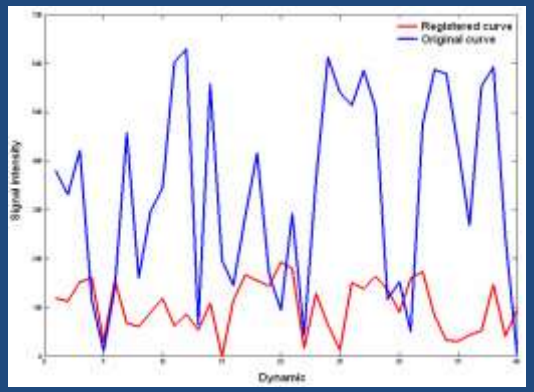


Acquisition and analysis of Biomarkers: Liver

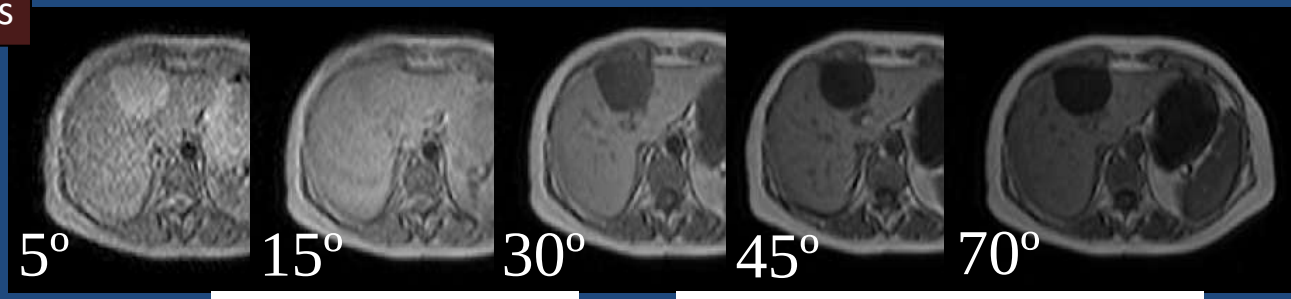
Proof of | Proof of | Image | Image preparation | Image processing | Measurement | Proof of principle | Proof of efficacy and effectiveness | Structured report

Registration
Movement correction
Rigid + elastic deformation models



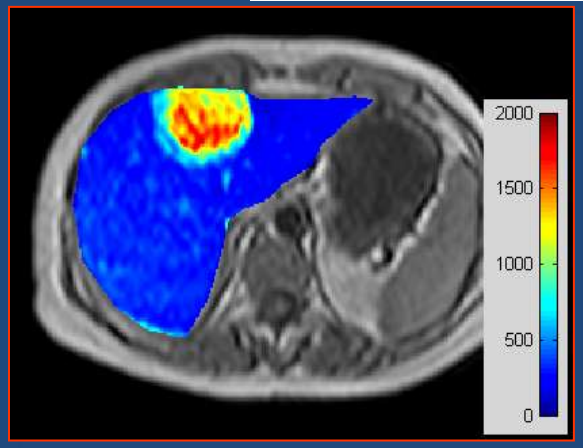


Intensity to Concentration conversion



$$C(t) = \frac{\frac{1}{T1(t)} - \frac{1}{T1(0)}}{r1}$$

$$S(\alpha) = M \cdot \sin\alpha \frac{1 - e^{-\frac{TR}{T1}}}{1 - \cos\alpha \cdot e^{-\frac{TR}{T1}}}$$



Acquisition and analysis of Biomarkers: Bone

Proof of concept → Proof of mechanism → Image acquisition → **Image preparation** → Image processing → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

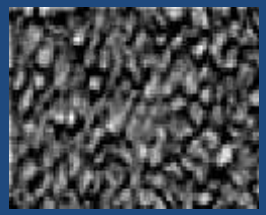
Segmentation

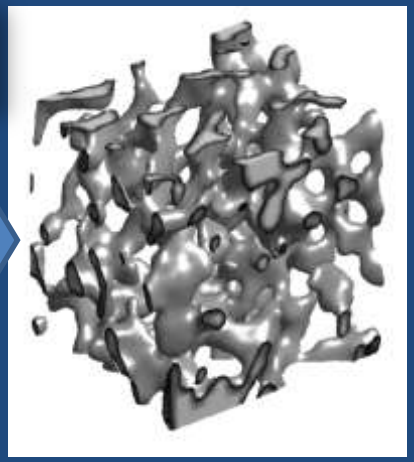
Equalization

Sub-voxel processing

Binarization

3D model

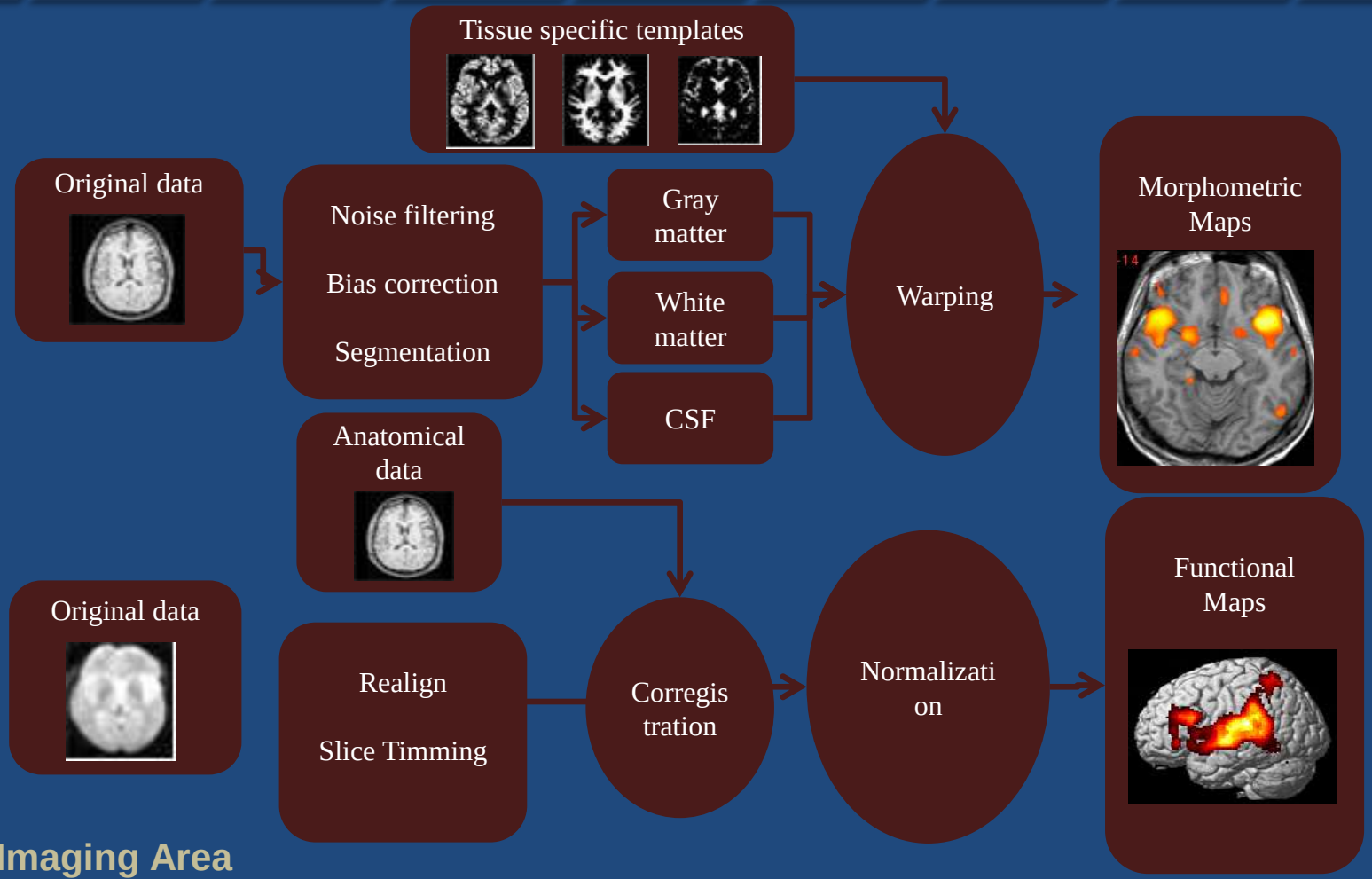




Medical Imaging Area

Acquisition and analysis of Biomarkers: Brain

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → **Image processing** → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report



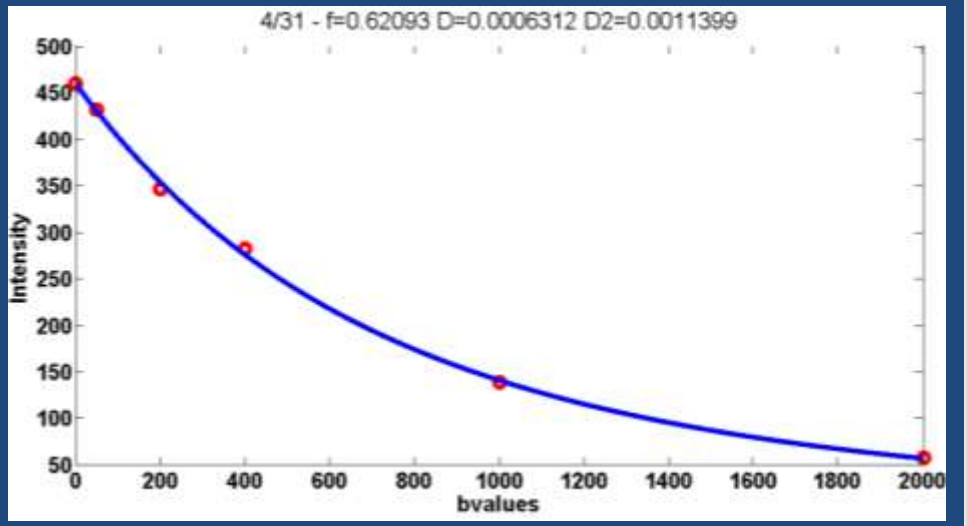
Acquisition and analysis of Biomarkers: Prostate

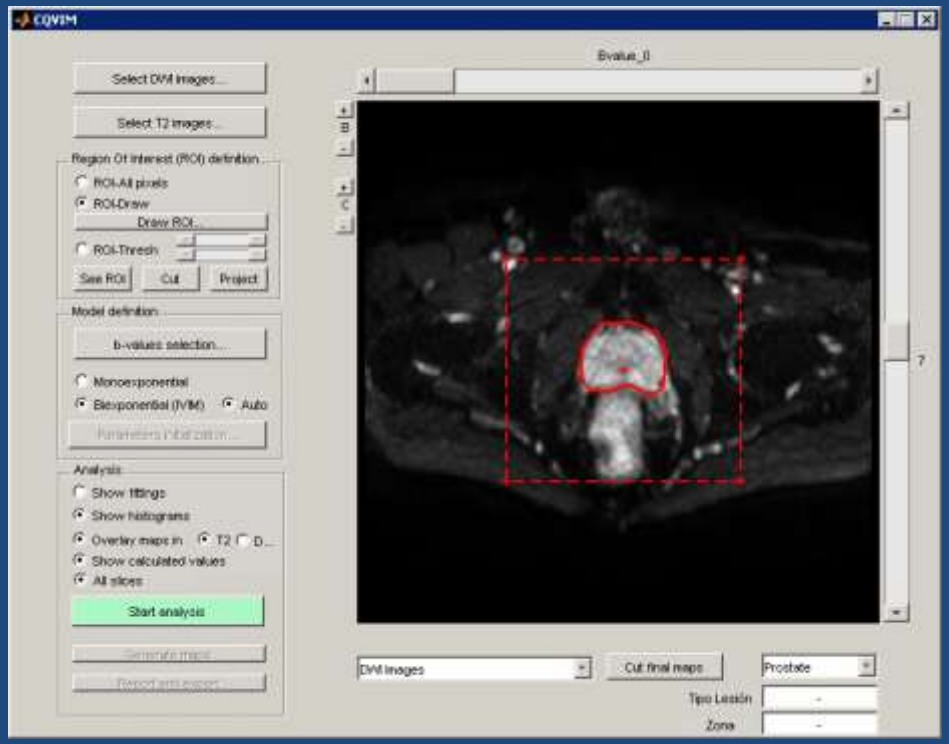
Proof of concept | Proof of mechanism | Image acquisition | Image preparation | **Image processing** | Measurement | Proof of principle | Proof of efficacy and effectiveness | Structured report

Calculation of diffusion properties by the application of the IVIM model

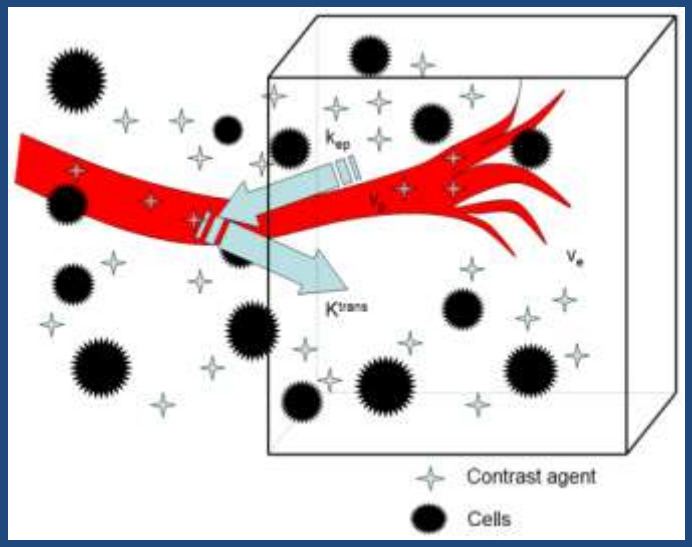
- Voxel-by-voxel analysis
- Curve fitting
- Calculation of D, D* and f

$$S_I = S_0 \cdot f \cdot e^{-b\cdot(D+D^*)} + S_0 \cdot (1-f) \cdot e^{-b\cdot D}$$





Acquisition and analysis of Biomarkers: Cartilage



Pharmacokinetic modeling (PKM)

- Arterial capillary permeability: **K^{trans}** (ml/min/100ml)
- Washout rate: **k_{ep}** (ml/min/100ml)
- 1st compartment: vascular space fraction: **v_p** (%)
- 2nd compartment: interstitial space fraction: **v_e** (%)

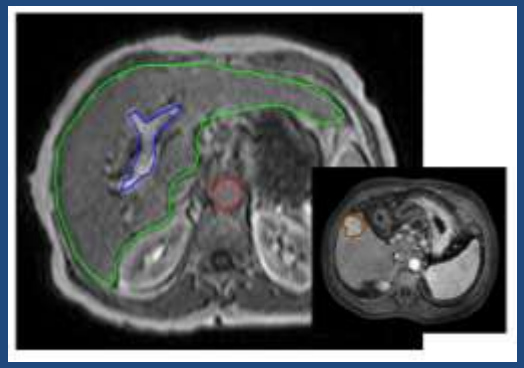
$$C_t(t) = v_p C_a(t) + \int_0^t K^{trans1} C_a(t) e^{-k_{ep}(t-t)} dt$$

Tissue uptake | Vascular part | Interstitial part

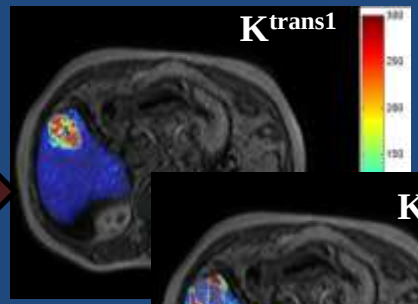
$$v_e = \frac{K^{trans}}{k_{ep}}$$

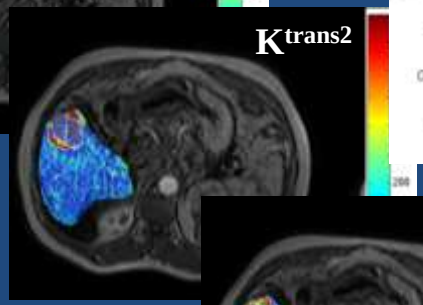
Acquisition and analysis of Biomarkers: Liver

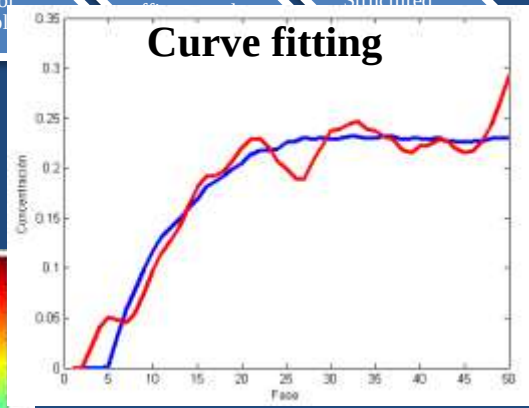
Proof of concept → Proof of mechanism → Image acquisition → Image preparation → **Image processing** → Measurement → Proof of principl → Proof of → Structured

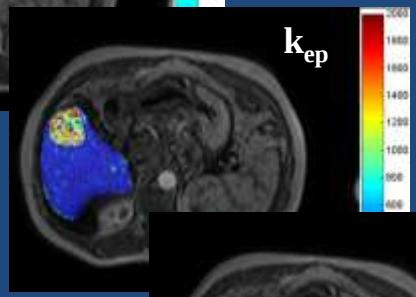


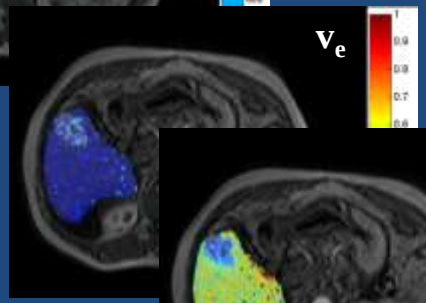
Voxel-based analysis

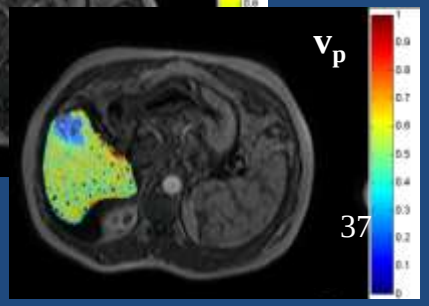


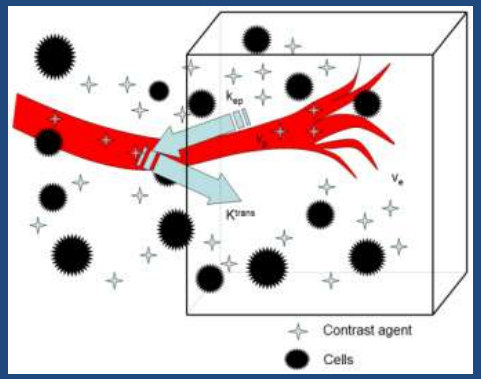












Pharmacokinetic modeling

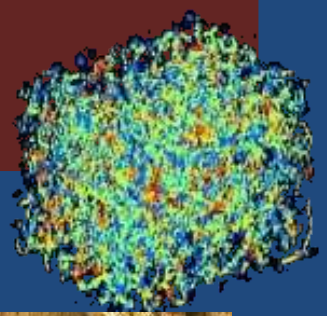
- Arterial / Venous permeability: K^{trans1} / K^{trans2} (ml/min/100ml)
- k_{ep} (ml/min/100ml)
- v_p (%)
- v_e (%)

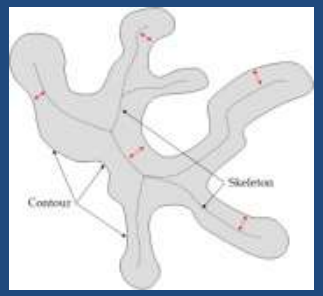
Acquisition and analysis of Biomarkers: Bone

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → **Image processing** → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

Morphometry

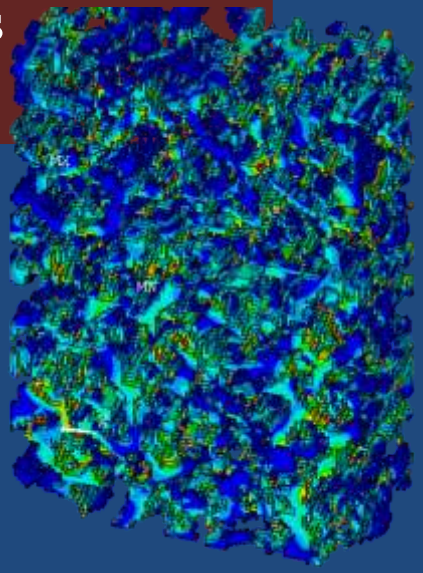
1. Morphology
2. Fractal complexity
3. Topology
4. Anisotropy





Mechanical

1. Meshing
2. Model generation
3. Model simulation
4. Young's modulus estimation



Acquisition and analysis of Biomarkers

Innovación y experiencia al servicio del paciente

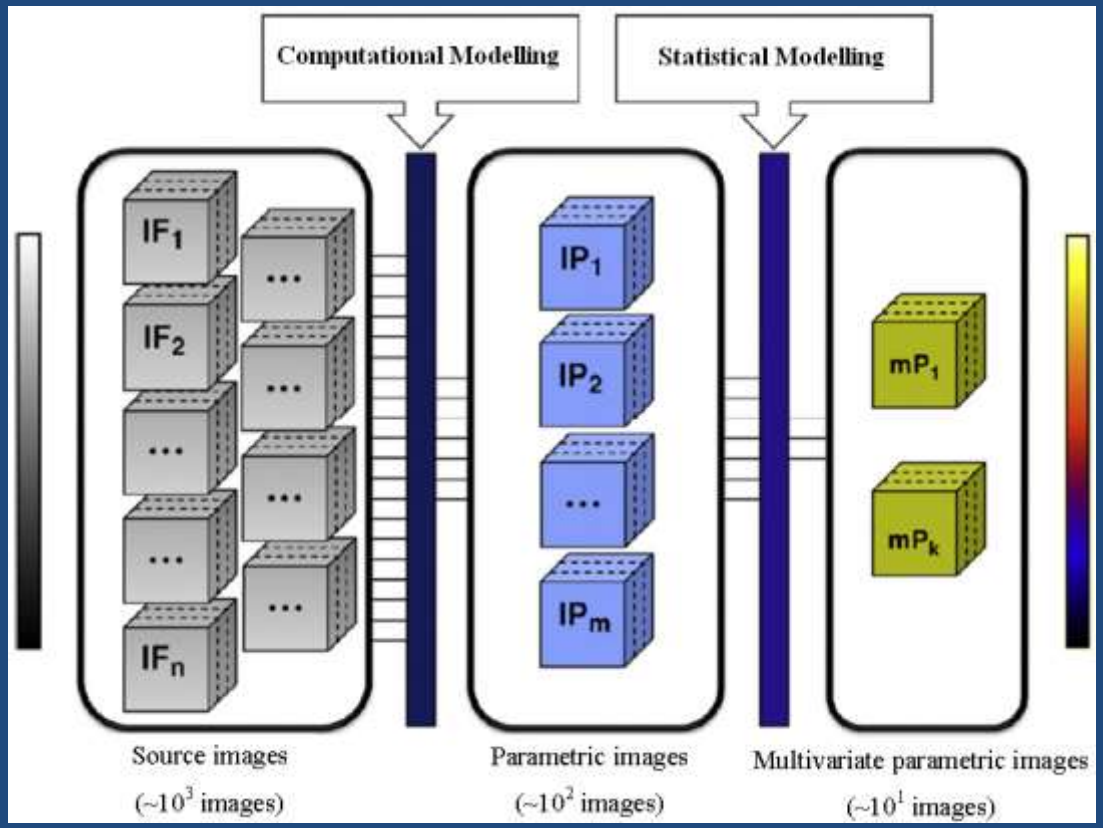
Proof of concept → Proof of mechanism → Image acquisition → Image preparation → **Image processing** → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report

Image processing

Extract information about the biomarkers from the digital images using the appropriate computational processes.

Parametric images depict the spatial distribution of the biomarker.

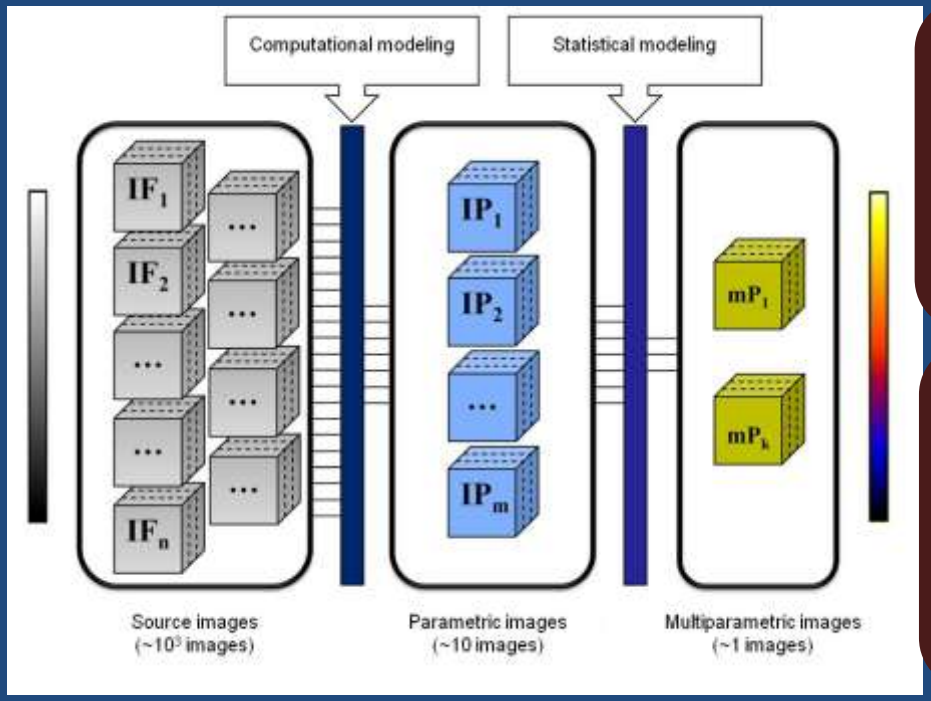
In multivariate images, the colour of each voxel is determined by a multivariate statistical function, which is in turn a combination of several parameters or biomarkers.



Biomarker measurement: Brain

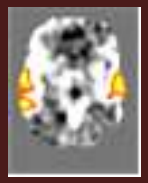
Innovación y experiencia al servicio del paciente

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → **Image processing** → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report



Original structural data

Functional Contrast Maps



Morphometry with selected ROIS

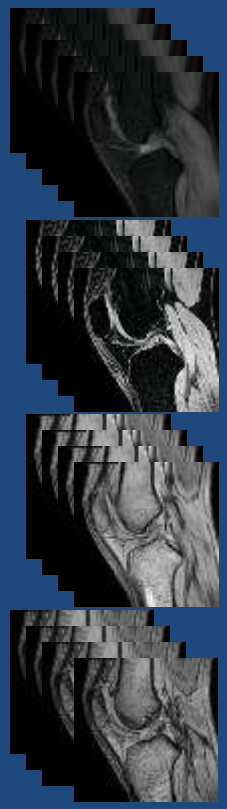
Functional with ROI selection

Coincidence Maps

Multivariate approach

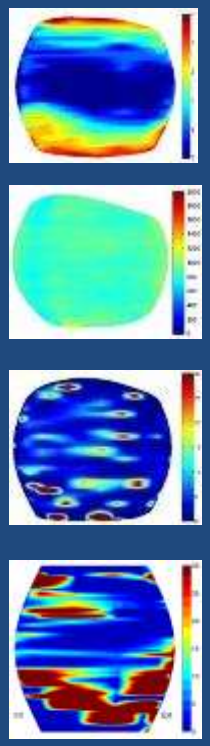
Biomarker Multivariate Approach

Source images



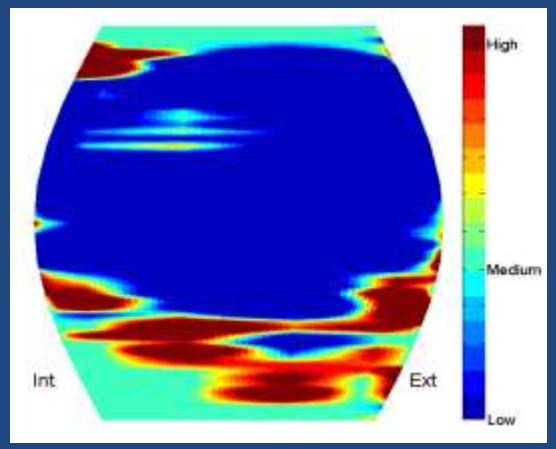
Computational models

Parametric images



Statistical models

Nosologic image



Relevance

Redundancy

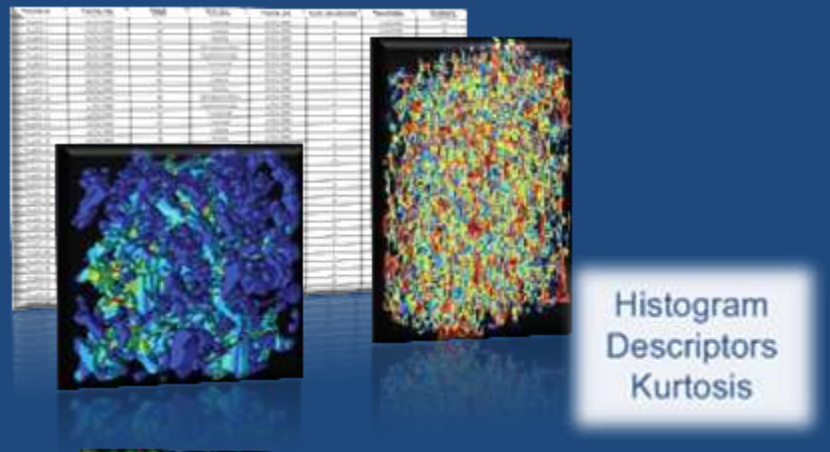
Biomarker measurement

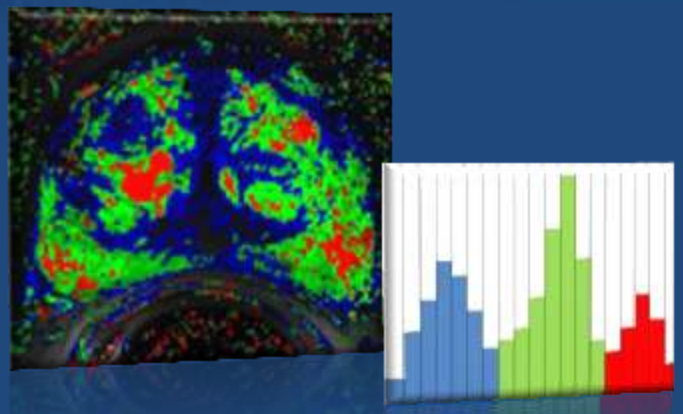
Innovación y experiencia al servicio del paciente

Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | **Measurement** | Proof of principle | Proof of efficacy and effectiveness | Structured report

Measurement

Parametric images, both conventional and multivariate, provide measurements from either the whole tissue or organ being studied or only from those areas considered more representative or abnormal (histograms analysis).



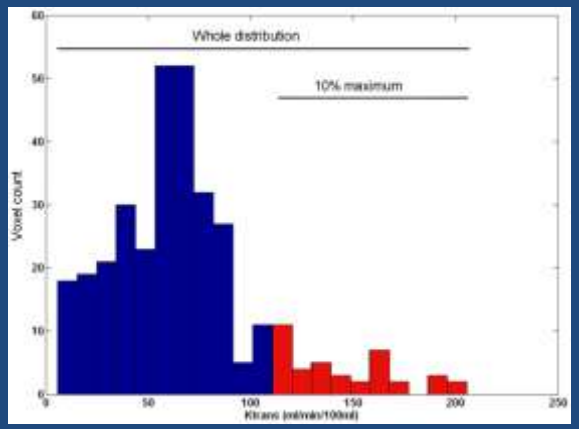


Biomarker measurement: Cartilage

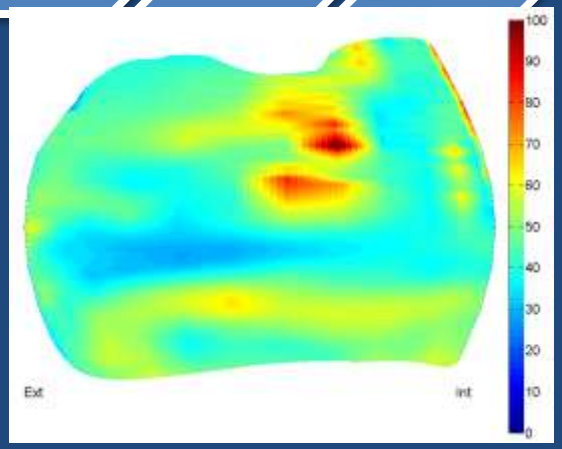
Innovación y experiencia al servicio del paciente

Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | **Measurement** | Proof of principle | Proof of efficacy and effectiveness | Structured report

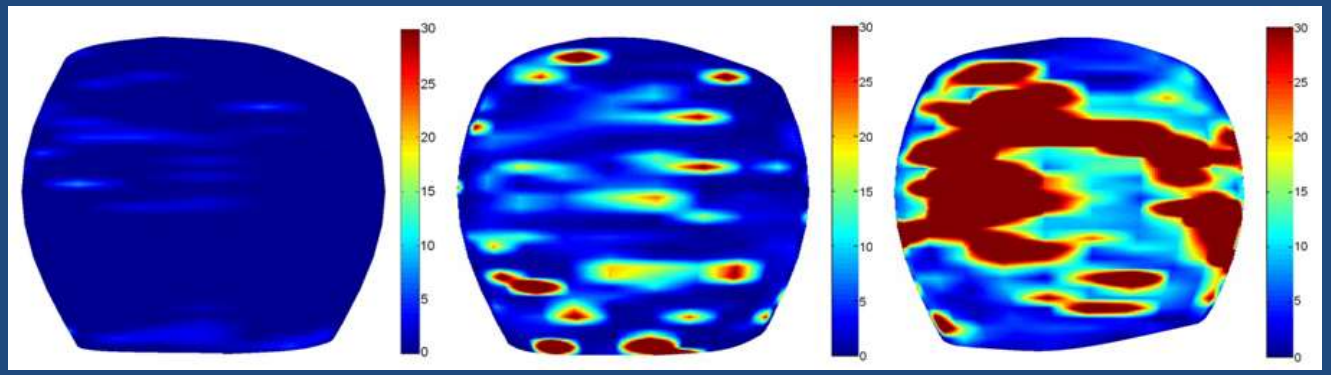
What should we measure?



Parametric map of the cartilage surface representing the value of T2* (proportional to the amount of water [edema] and loss of collagen)



Parametric maps of capillary permeability (Ktrans) of the patellar joint cartilage

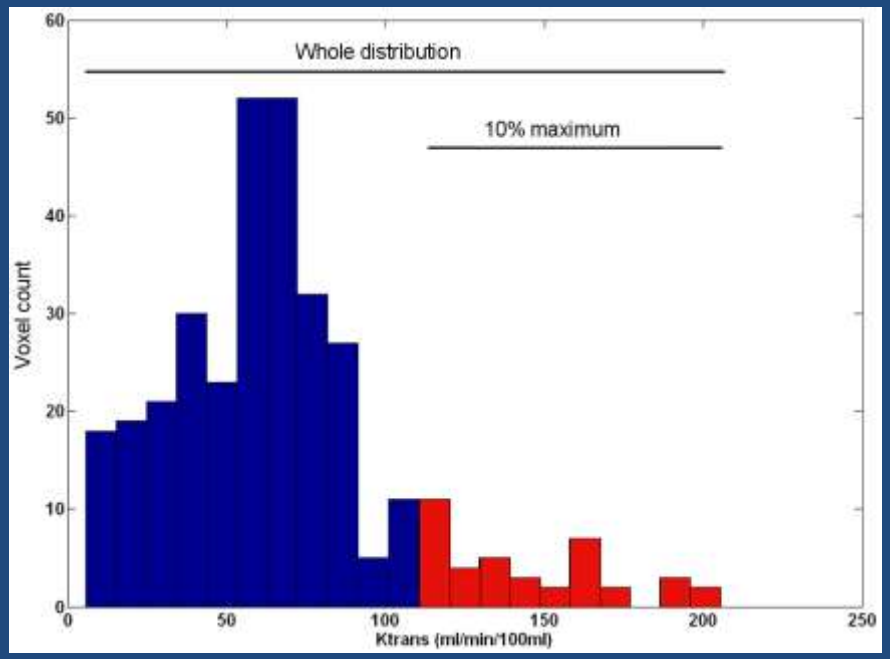


normal | chondromalacia | arthrosis

Biomarker measurement: Liver

Innovación y experiencia al servicio del paciente

Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | **Measurement** | Proof of principle | Proof of efficacy and effectiveness | Structured report



Mean – Standard deviation – Median

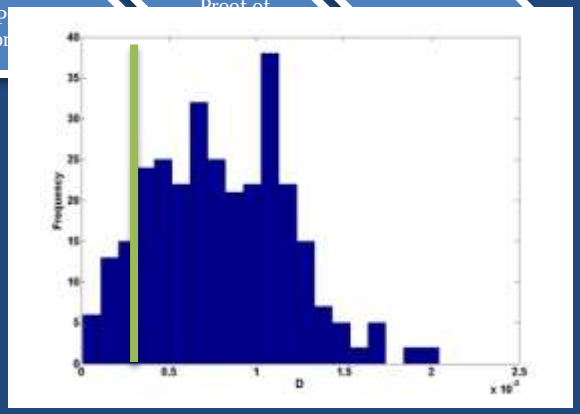
Asymmetry – Kurtosis – Relevant Percentiles (10%, 25%)

Heterogeneity : Histogram signature

Biomarker measurement: Prostate

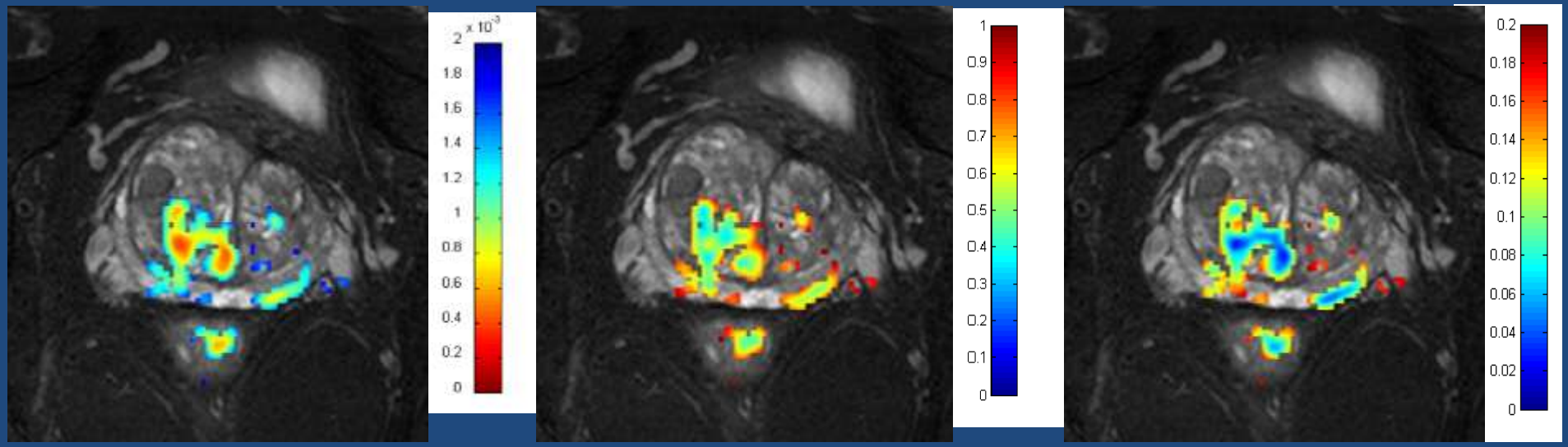
Innovación y experiencia al servicio del paciente

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurement → Proof of



Parametric mapping and ROI evaluation in DWI-IVIM:

- Histogram-based analysis of the diffusion parameters
- Parametric information overlay on anatomic images
- Threshold results for the depiction of regions with a higher water restriction.



D f D*

Biomarker measurement: Bone

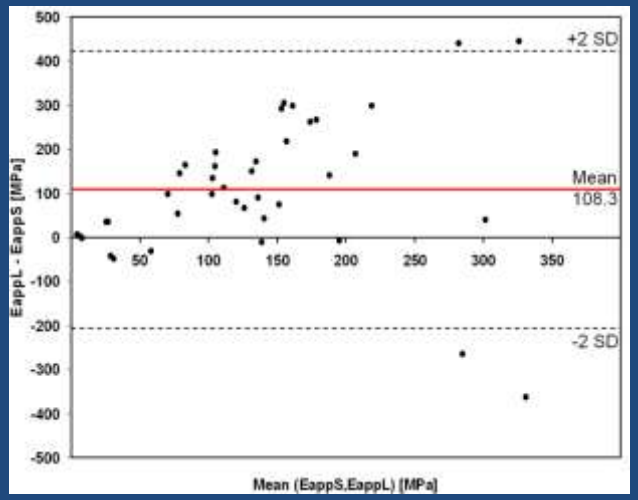
Innovación y experiencia al servicio del paciente

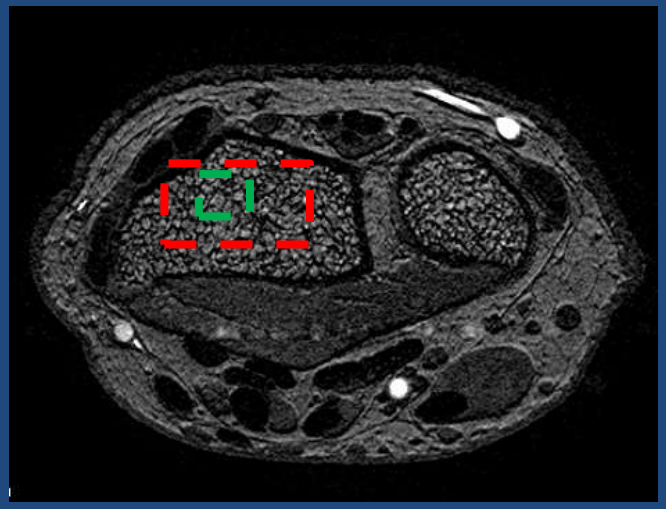
Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | **Measurement** | Proof of principle | Proof of efficacy and effectiveness | Structured report

Healthy values

Morphologic Parameter	Men ($n = 19$)	Women ($n = 21$)	Total ($n = 40$)
Bone volume-to-total volume ratio	0.24 ± 0.01	0.21 ± 0.01	0.22 ± 0.01
Trabecular thickness (μm)	198.49 ± 3.19	190.35 ± 0.95	194.22 ± 1.70
Trabecular separation (μm)	816.52 ± 26.46	886.90 ± 24.61	853.47 ± 18.66
Trabecular number ($10^{-3} \cdot \mu m^{-1}$)	1.22 ± 0.04	1.10 ± 0.04	1.16 ± 0.03

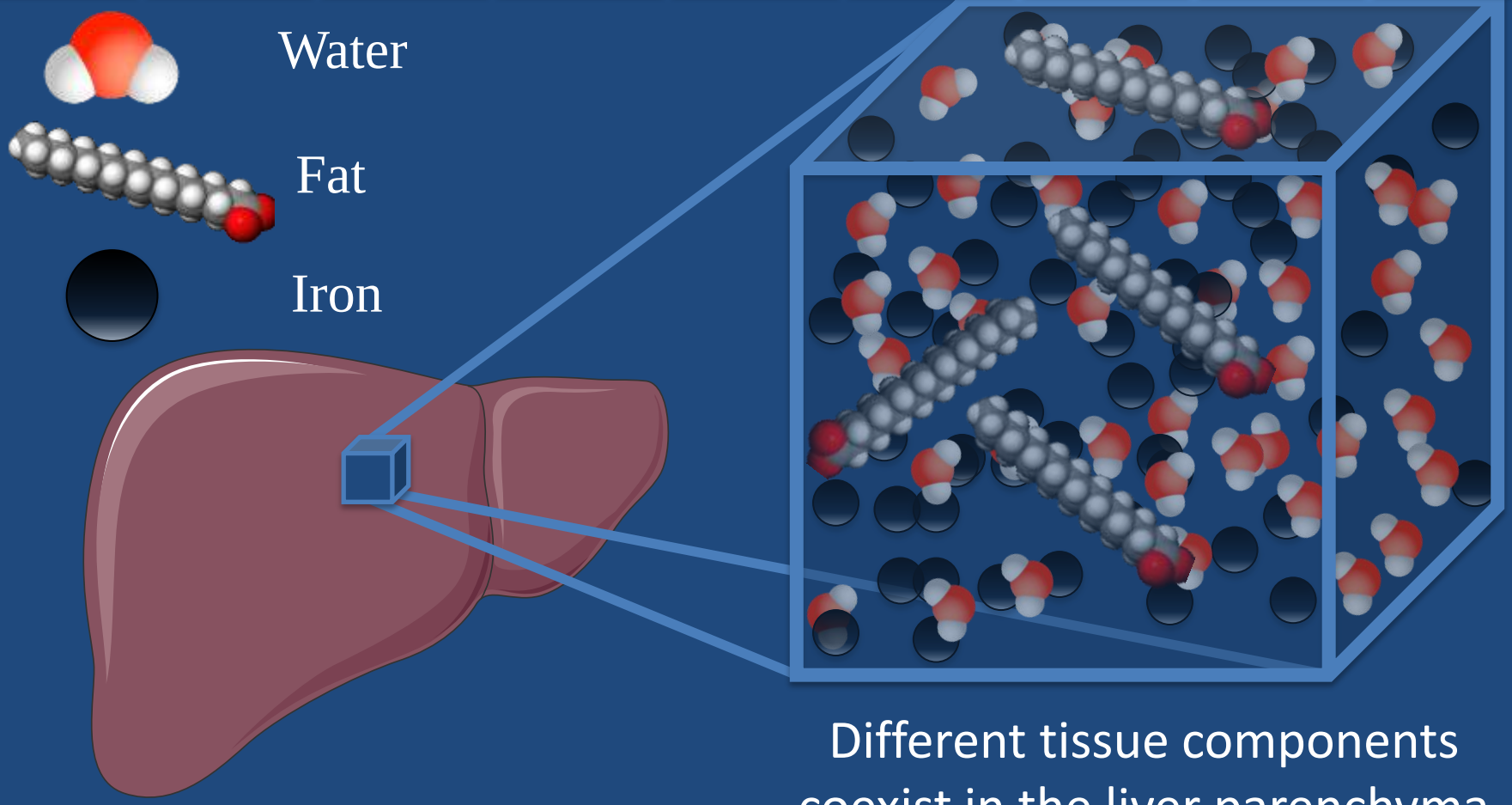
Bias: variations due to ROI dimensions





Fat-Water-Iron Liver Quantification

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → **Measurement** → Proof of principle → Proof of efficacy and effectiveness → Structured report



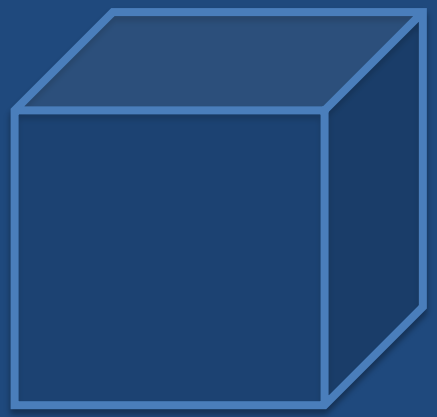
Different tissue components coexist in the liver parenchyma

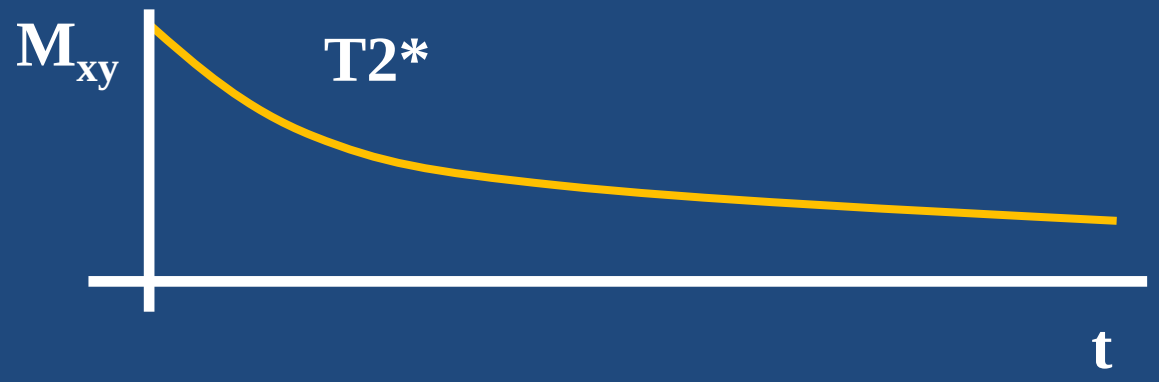
Fat-Water-Iron Liver Quantification

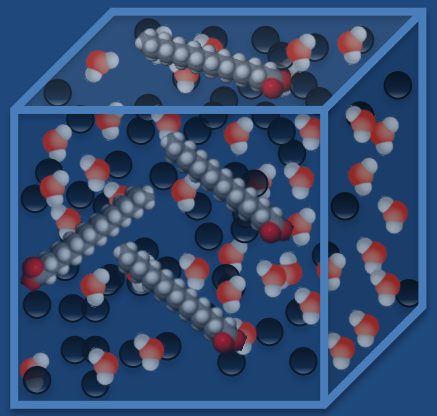
GENERALITAT VALENCIANA
La Fe
Hospital Universitari i Politècnic

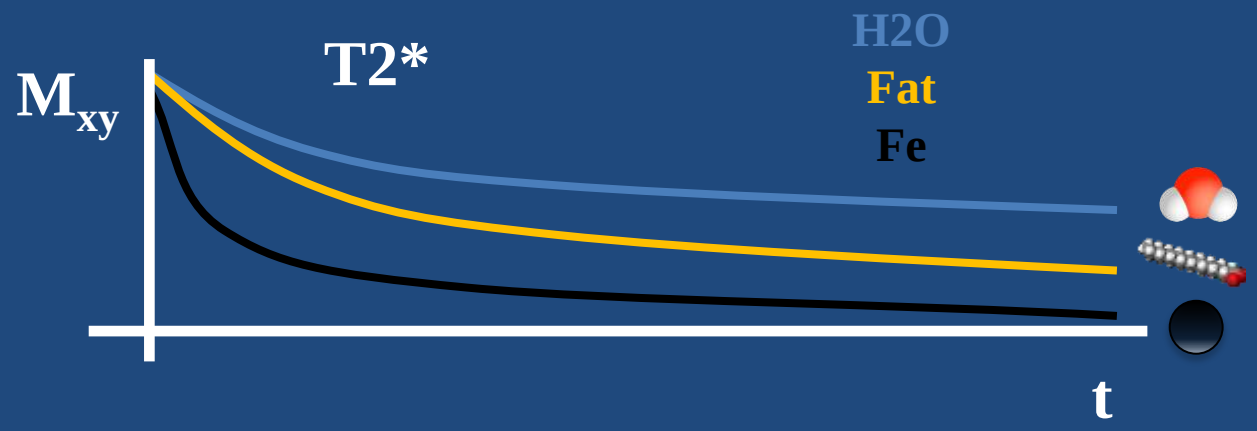
Innovación y experiencia al servicio del paciente

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → **Measurement** → Proof of principle → Proof of efficacy and effectiveness → Structured report









Biomarker validation

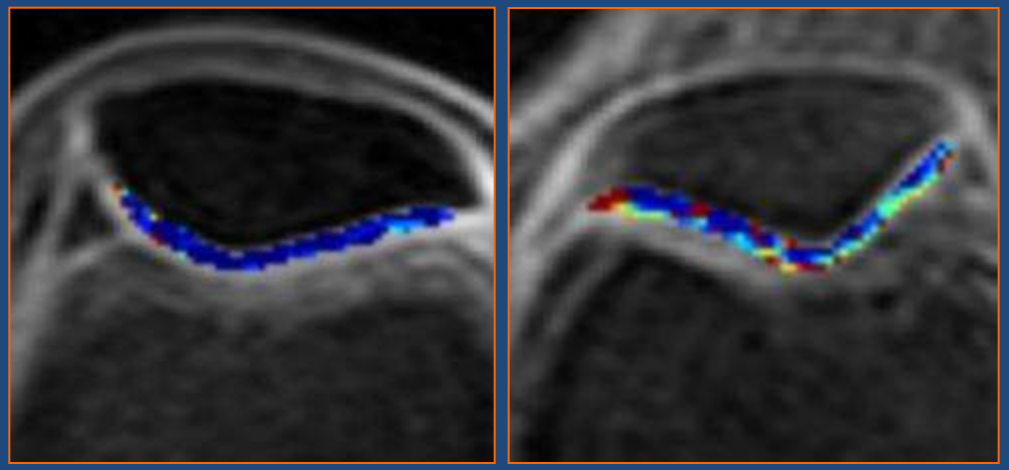
Innovación y experiencia al servicio del paciente

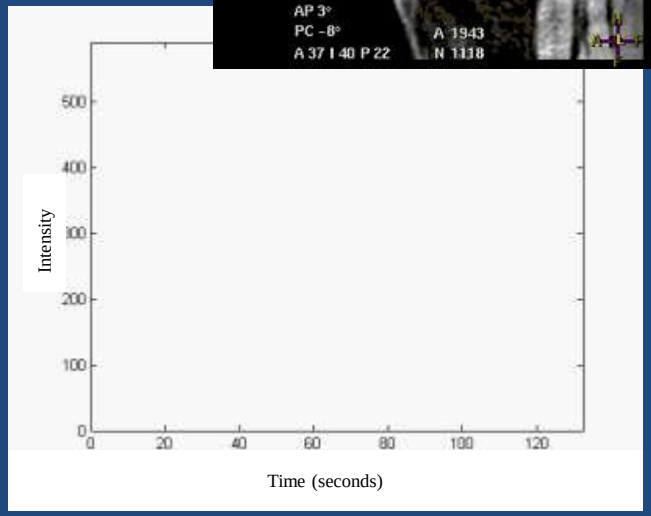
Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | Measurement | **Proof of principle** | Proof of efficacy and effectiveness | Structured report

Proof of Principle

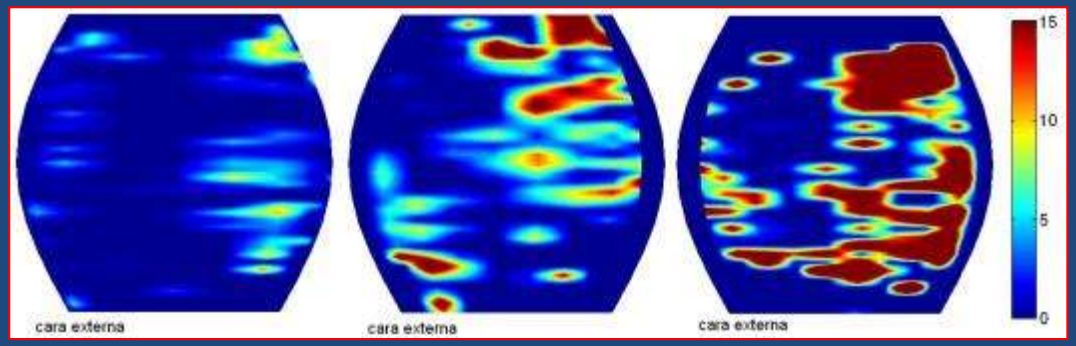
Validate the proof of concept and the proof of mechanism, which are both theoretical, in a small sample (case-control), before embarking on large-scale clinical trials.

Biomarkers Image

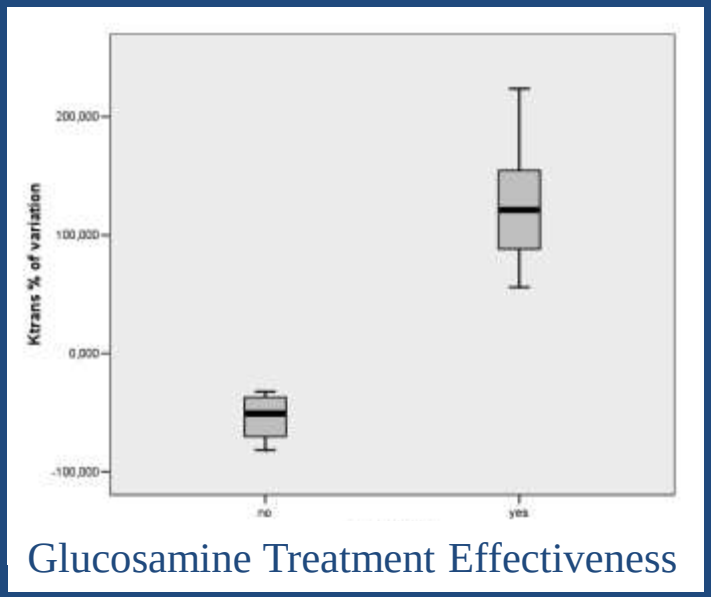




- **Permeability (Ktrans) parametric maps**



Normal Intermediate Advanced



Glucosamine Treatment Effectiveness

Sanz R, Martí-Bonmatí L, et al. J Magn Reson Imaging. 2008; 27:171-7.
Martí-Bonmatí L, Sanz R, et al. Eur Radiol 2009; ; 19:1512-1518

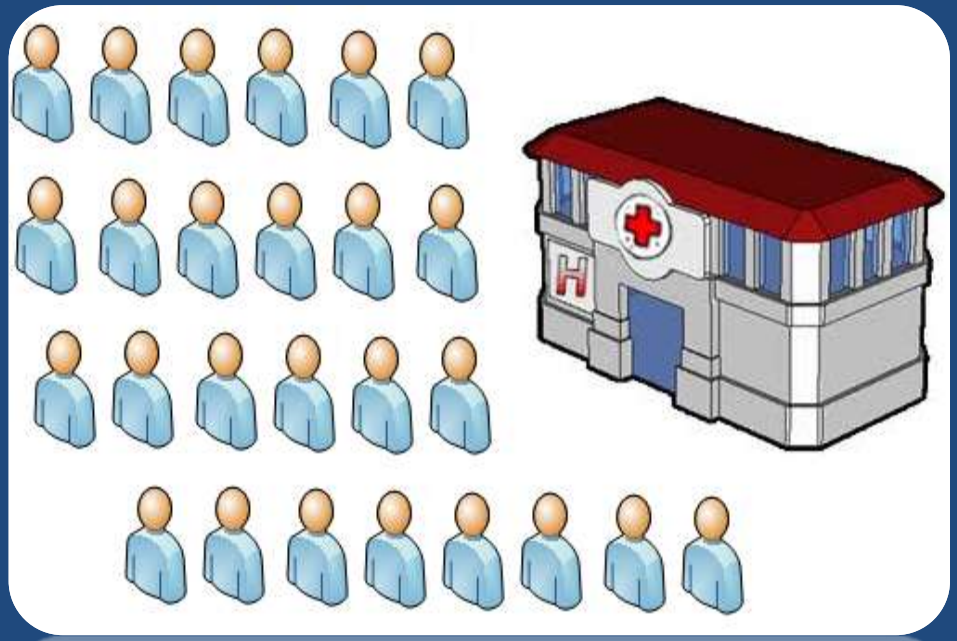
Biomarker validation

Innovación y experiencia al servicio del paciente

Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | Measurement | Proof of principle | **Proof of efficacy and effectiveness** | Structured report

Proof of Efficacy and Effectiveness

Analyze the ability of the biomarker in large sample sizes, studying the power of health technology both under perfect control (efficacy) and under usual (effectiveness) conditions.

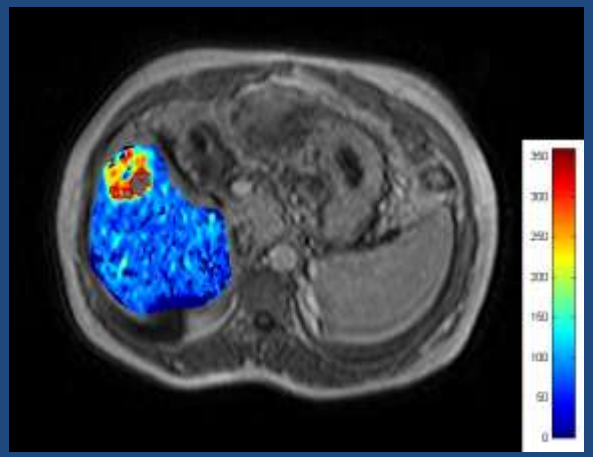


Biomarker validation: Liver

Innovación y experiencia al servicio del paciente

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurement → Proof of principle → **Proof of efficacy and effectiveness** → Structured report

- Measurements are potentially useful for intra-center studies:
  - Longitudinal studies with/without treatment
  - Intra-center normality values
- Reproducibility analysis are generally included:
  - Image acquisition and analysis methods
  - Inter- and intra-observer variability



But…

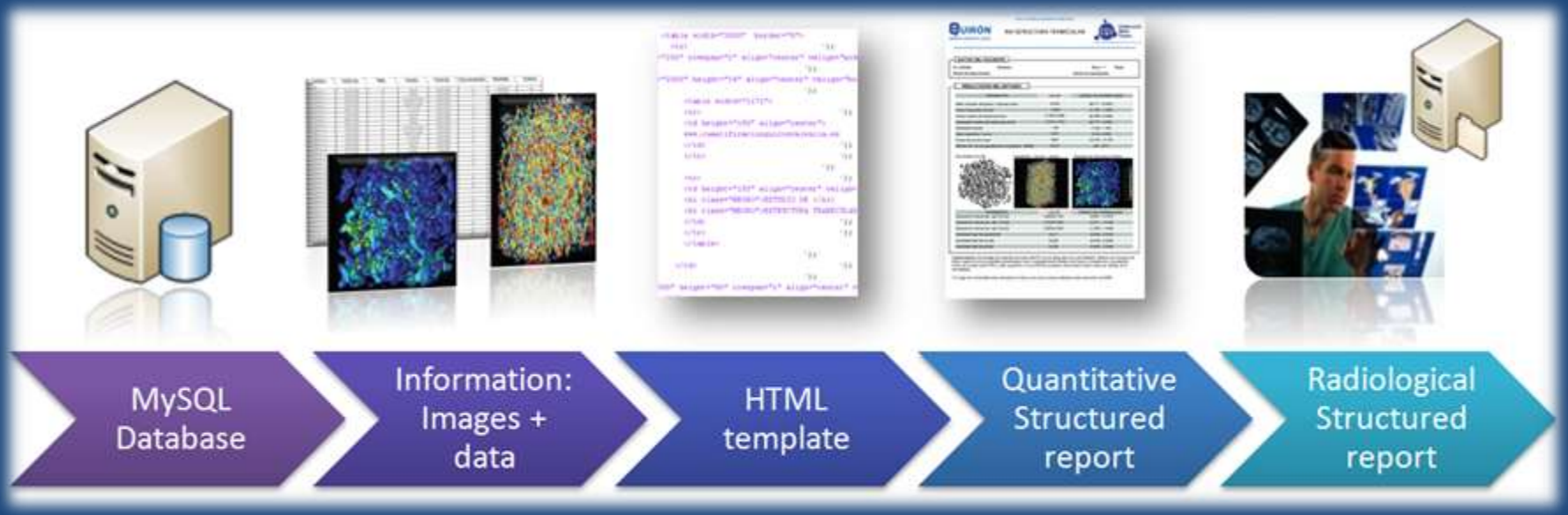
- Relatively few patients
- Lack of strong validation (clinical endpoints, anatomical-pathological proof, etc.)
- Difficulties for meta-analysis
- No true standards yet

So there is still a lot to do for the…

The Radiological Report with Biomarkers

Innovación y experiencia al servicio del paciente

Proof of concept → Proof of mechanism → Image acquisition → Image preparation → Image processing → Measurement → Proof of principle → Proof of efficacy and effectiveness → Structured report



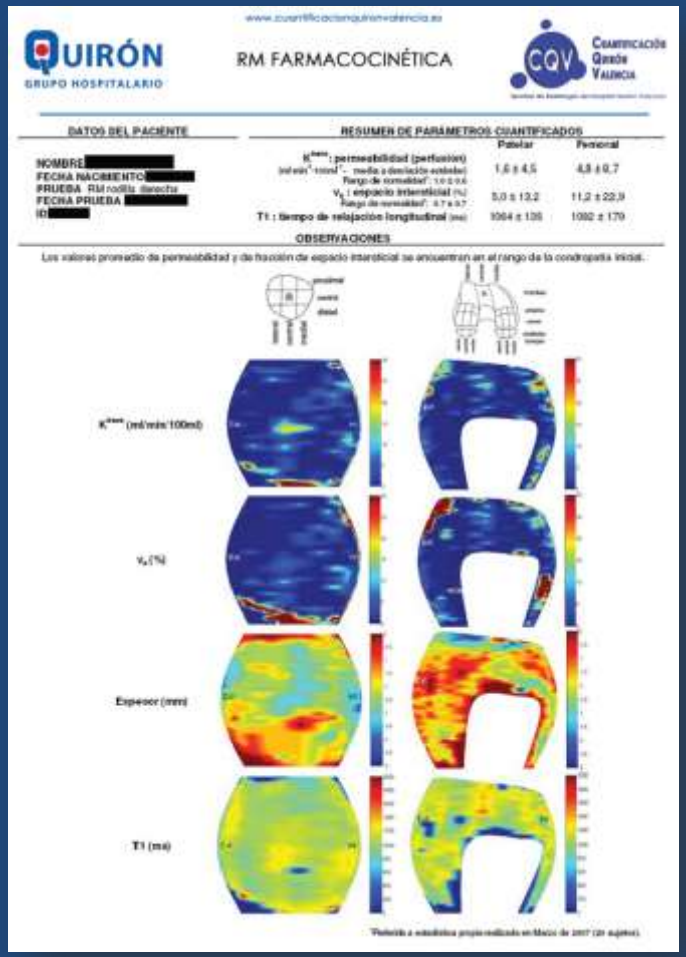
Structured Report

To innovate in clinical practice, the results provided by the biomarkers need to be conveyed in an intuitive way. The Structured Report (SR) must comprise complete and accurate information including the assessment of potential bias and a generalization of the results.

The Radiological Report with Biomarkers: Cartilage

Proof of concept | Proof of mechanism | Image acquisition | Image preparation | Image processing | Measurement | Proof of principle | Proof of efficacy and effectiveness | Structured report

Structured report



QUIRÓN GRUPO HOSPITALARIO

RM FARMACOCINÉTICA

CQV Cuantificación Quirón Valencia

DATOS DEL PACIENTE

NOMBRE [redacted]
FECHA NACIMIENTO [redacted]
PRUEBA RM rodilla derecha
FECHA PRUEBA [redacted]
ID [redacted]

RESUMEN DE PARÁMETROS CUANTIFICADOS

	Patelar	Femoral
K^{trans} : permeabilidad (perfusión) (ml/min/100ml) - media ± desviación estándar; Rango de normalidad*	1,6 ± 4,5	4,8 ± 0,7
V_e : espacio intersticial (%); Rango de normalidad*	5,0 ± 13,2	11,2 ± 22,9
T1 : tiempo de relajación longitudinal (ms)	1064 ± 135	1092 ± 170

OBSERVACIONES

Los valores promedio de permeabilidad y de fracción de espacio intersticial se encuentran en el rango de la condropatía inicial.

K^{trans} (ml/min/100ml)

V_e (%)

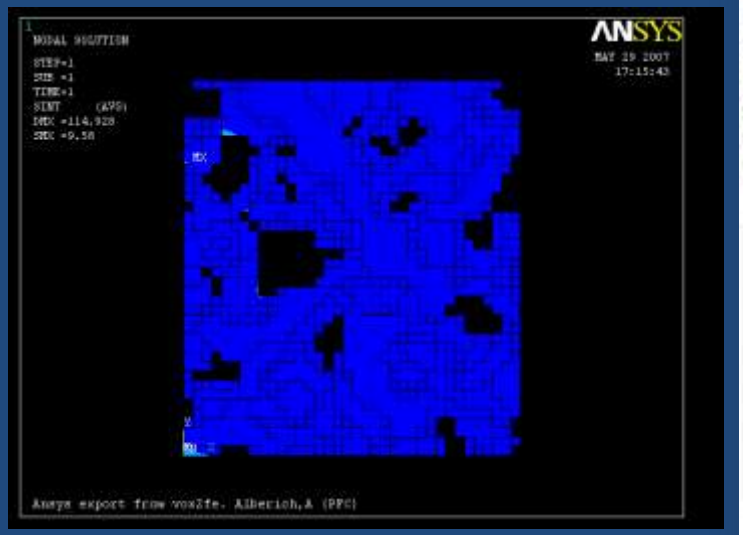
Espesor (mm)

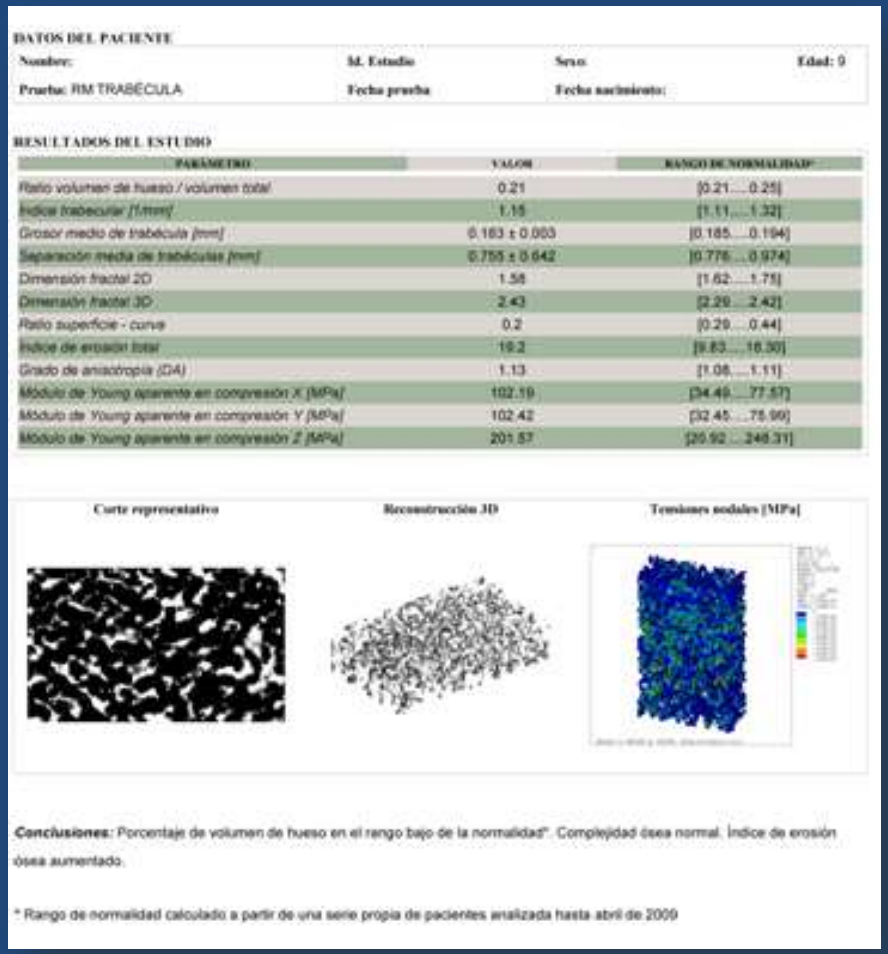
T1 (ms)

*Patrón a estudiarse proyecto realizado en Marzo de 2007 (20 sujetos)

The Radiological Report with Biomarkers: Bone

Structured report





DATOS DEL PACIENTE

Nombre:	Id. Estudio	Sexo	Edad: 9
Prueba: RM TRABÉCULA	Fecha prueba	Fecha nacimiento:	

RESULTADOS DEL ESTUDIO

PARÁMETRO	VALOR	RANGO DE NORMALIDAD*
Ratio volumen de hueso / volumen total	0.21	[0.21....0.25]
Índice trabecular [1/mm]	1.15	[1.11....1.32]
Grosor medio de trabécula [mm]	0.183 ± 0.003	[0.185....0.194]
Separación media de trabéculas [mm]	0.755 ± 0.642	[0.776....0.974]
Dimensión fractal 2D	1.58	[1.62....1.75]
Dimensión fractal 3D	2.43	[2.29....2.42]
Ratio superficie - curva	0.2	[0.29....0.44]
Índice de erosión total	19.2	[9.83....16.30]
Grado de anisotropía (DA)	1.13	[1.08....1.11]
Módulo de Young aparente en compresión X [MPa]	102.19	[34.49....77.57]
Módulo de Young aparente en compresión Y [MPa]	102.42	[32.45....75.99]
Módulo de Young aparente en compresión Z [MPa]	201.57	[20.92....246.31]

Corte representativo | Reconstrucción 3D | Tensiones nodales [MPa]

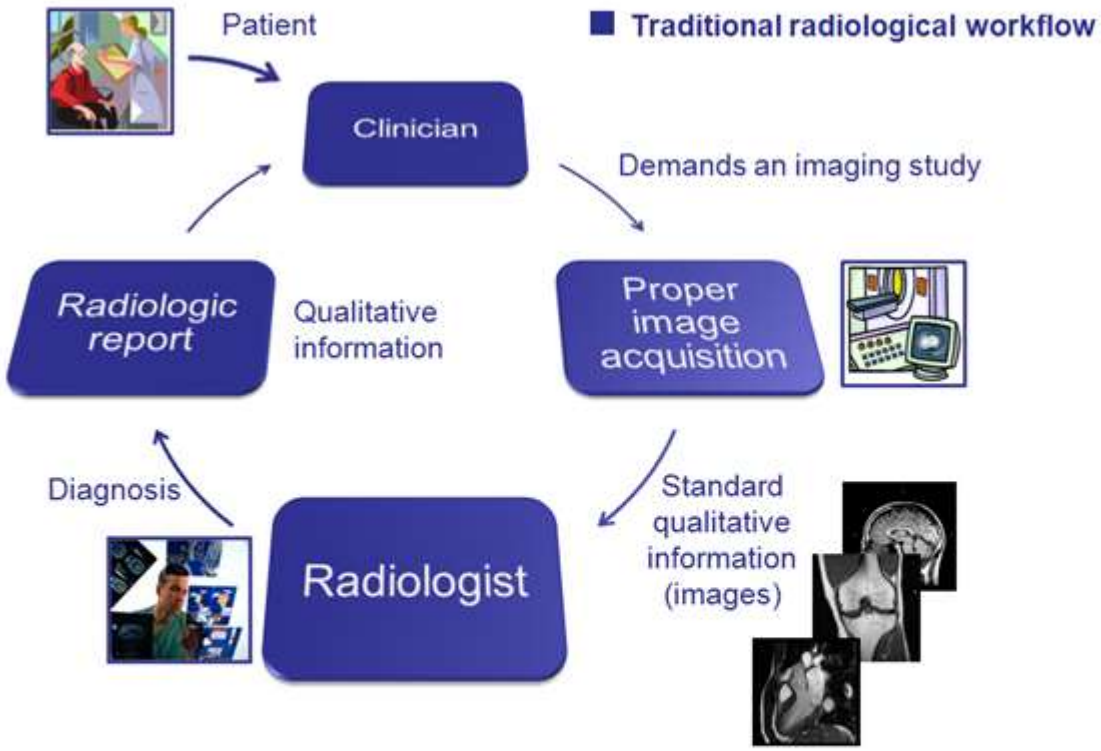
Conclusiones: Porcentaje de volumen de hueso en el rango bajo de la normalidad*. Complejidad ósea normal. Índice de erosión ósea aumentado.

* Rango de normalidad calculado a partir de una serie propia de pacientes analizada hasta abril de 2009

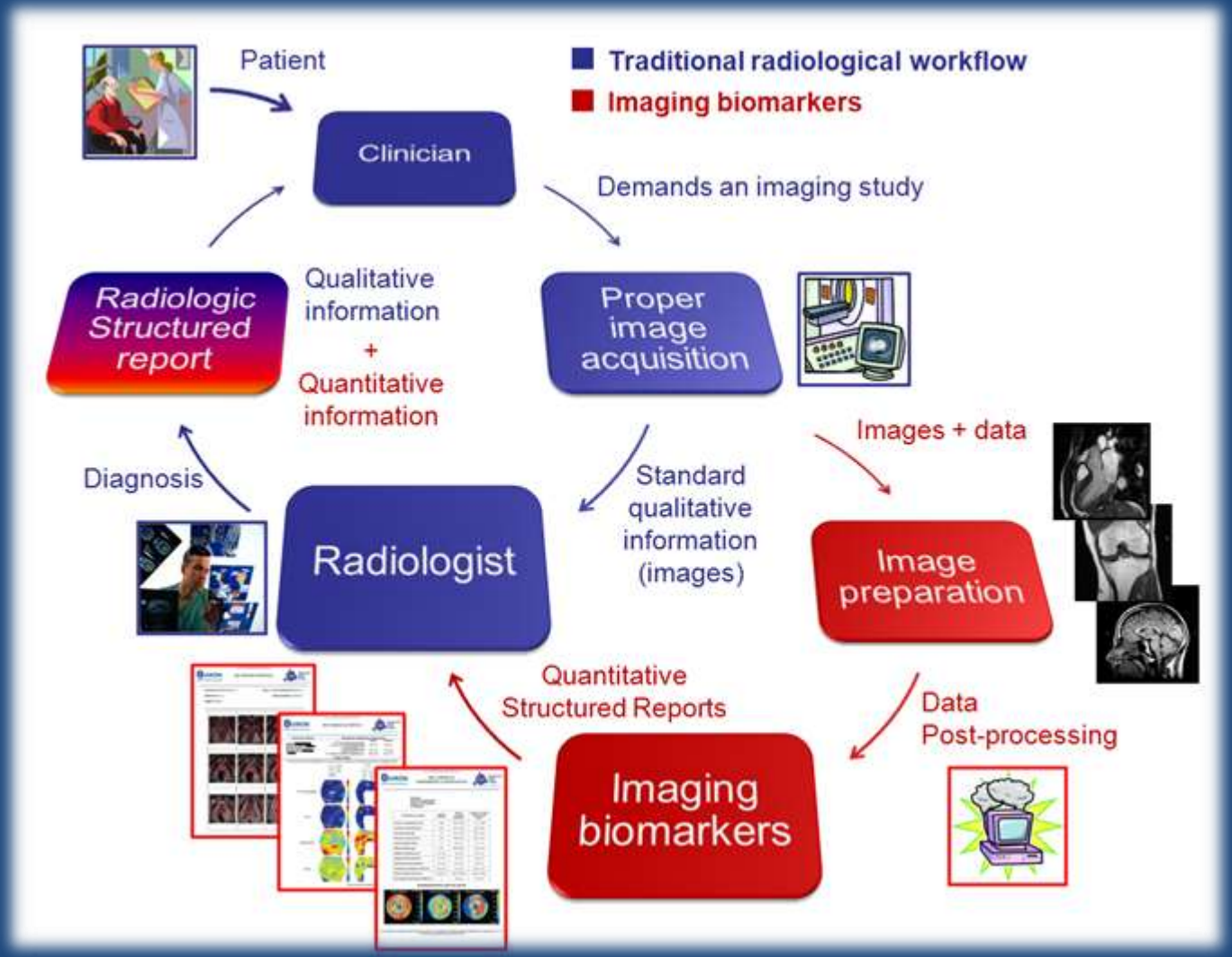
Joint Cartilage Example

1. MR images in high resolution digital format, suitable for morphological, structural and functional analysis of the cartilage
2. Segmentation of the cartilage for its regional analysis (pixel by pixel)
3. Quantitative parameterization of thickness, T1 and T2 relaxation times, pharmacokinetic parameters, delayed enhancement
4. Validation of the reproducibility, bias and normality ranges
5. Validation of the clinical efficacy in the diagnosis, grading and monitoring of the disease

Biomarkers and Medical Imaging



Biomarkers and Medical Imaging



Radiologic Workflows

Innovación y experiencia al servicio del paciente

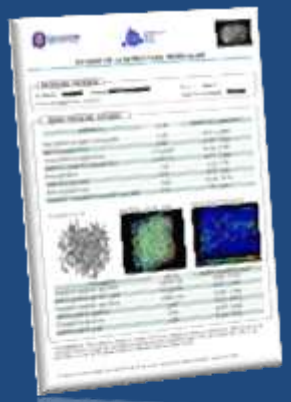
Study Demand

Specific meetings
Multidisciplinary committees
Treatment planning and monitoring
Clinical research

Appropriateness
Decision Support Systems
Adequate protocol and algorithm
Clinical situation

Consultancy

Citation



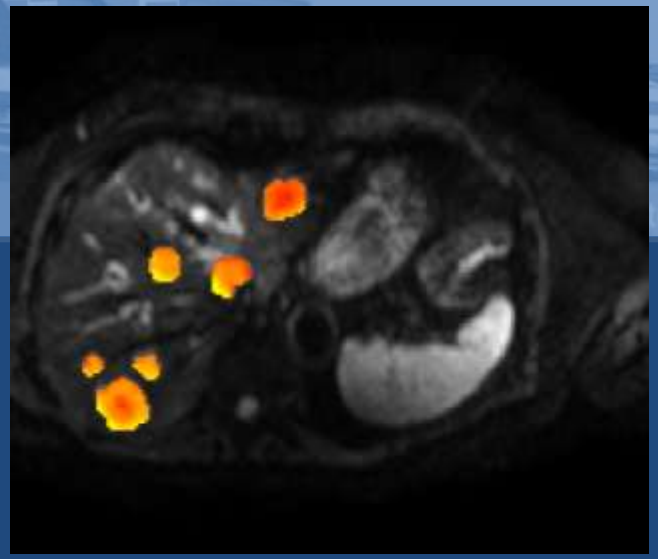
Performance

Technical Quality
Innovation Criteria
Standardization
Use of Biomarkers
Workload
RIS - PACS

Report

Standardized Structured reporting
Diagnosis assistance
Effective communication
Second opinion

Conclusion



- ✓ Digital medical imaging and computer processing allow to extract parametrizable information that can be considered functional or structural imaging biomarkers.
- ✓ In clinical practice, these biomarkers can be of great interest because of the benefits they provide to the diagnostic, treatment and follow-up processes in numerous diseases.
- ✓ The integrity of imaging biomarkers cycle should be controlled from conception to implementation.
- ✓ The combination of digital imaging, contrast media and computer processing is some kind of magic, where the occult and mysterious becomes visible. Its ultimate goal is to achieve professional success, understood as excellence in personalized-care medicine.
- ✓ **All these advantages are the result of multidisciplinary work of different professionals who come together to provide a better patient care and a greater biological understanding of the diseases.**