



Innovación en Cardiología: *Oportunidades y Retos*

Jose M de la Torre Hernandez

Jefe del Servicio de Cardiología, HUMV, Santander
Vicepresidente de la Sociedad Española de Cardiología



Años 90

Compañía X:

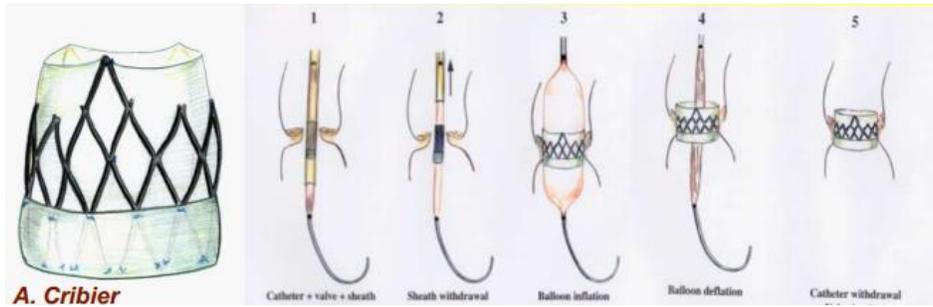
“La idea mas estúpida que oí jamás”

Compañía Y:

“Totalmente irrelevante”

Compañía Z:

“Limitaciones técnicas insuperables ”



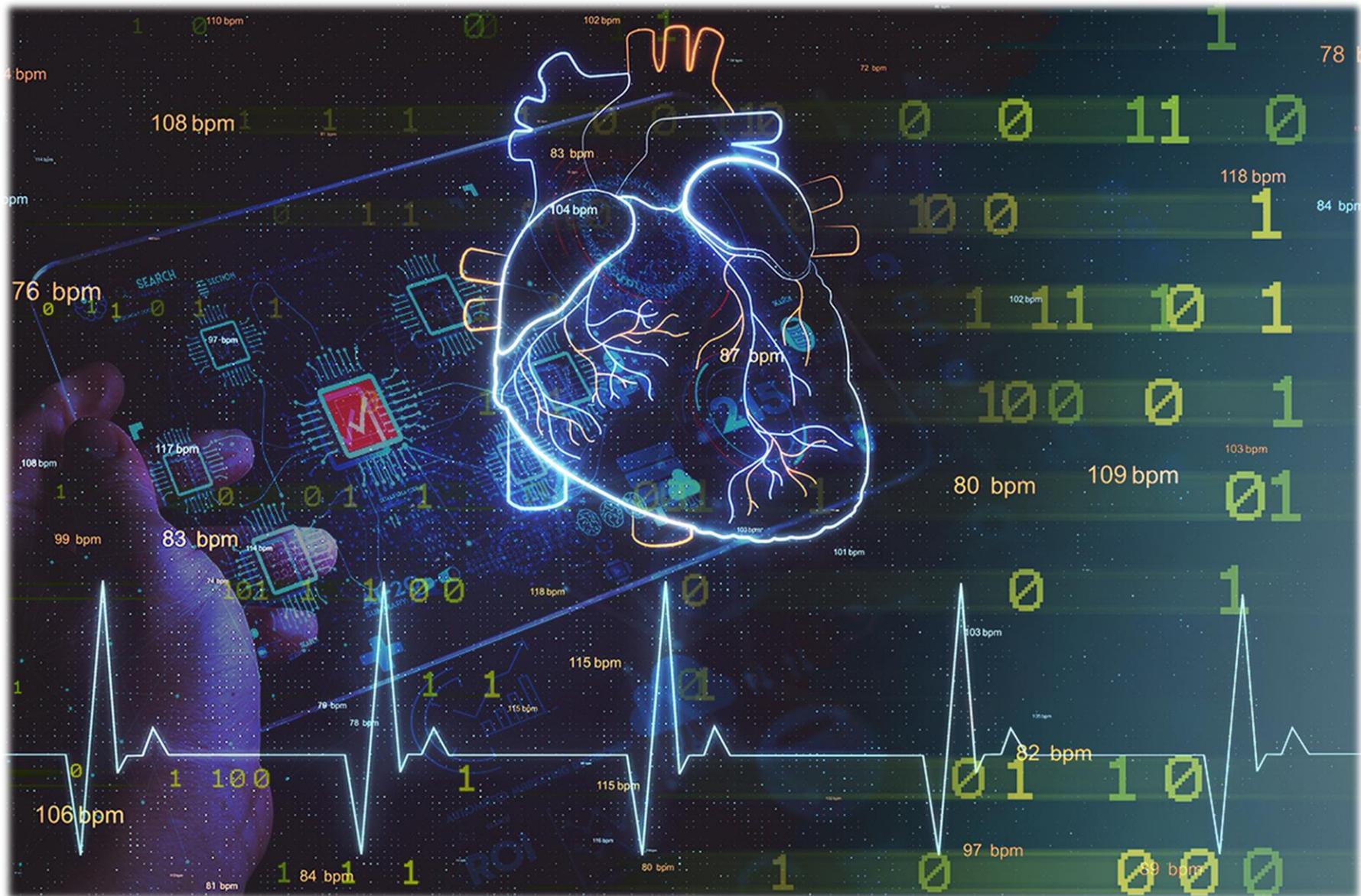
2002



In Memoriam: Alain Cribier, MD, FACC, TAVR Pioneer



Febrero de 2024



CARDIOLOGY, AT THE HEART OF INNOVATION



- 1923 -
World's first successful heart valve surgery

- 1947 -
First defibrillator developed and first successful defibrillation

- 1929 -
First right heart catheterization performed by Werner Forssmann on himself

- 1958 -
First fully implantable pacemaker



- 1952 -
First use of the thrombolytic enzymes to dissolve blood clots in the heart

- 1960 -
First mechanical aortic heart valve successfully implanted



- 1967 -
World's first successful human heart transplant

- 1982 -
First permanent artificial heart was transplanted



- 1986 -
First coronary stents implanted by Ulrich Sigwart and Jacques Puel at CHUV Lausanne



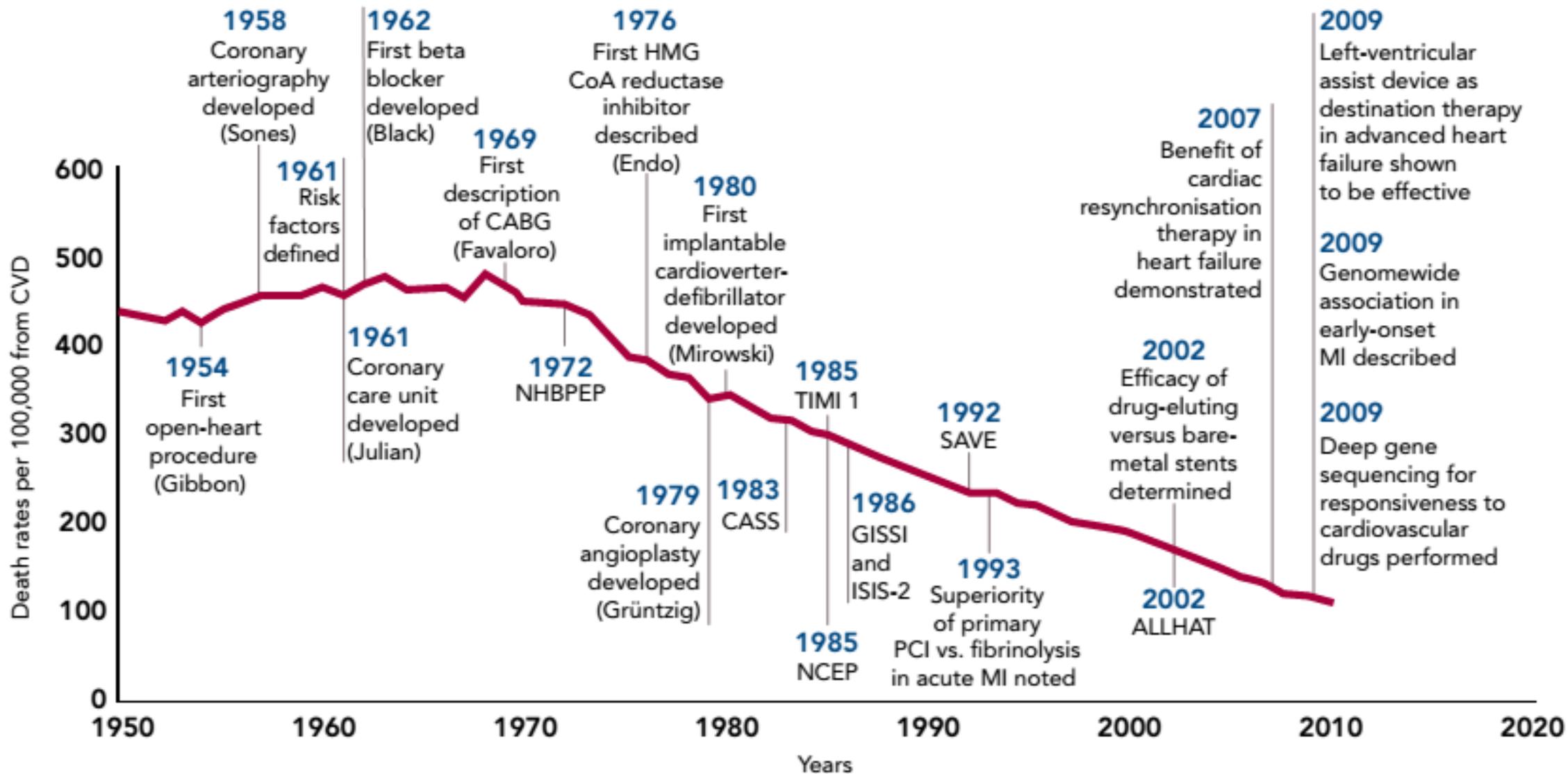
- 2002 -
First transcatheter aortic valve replacement performed

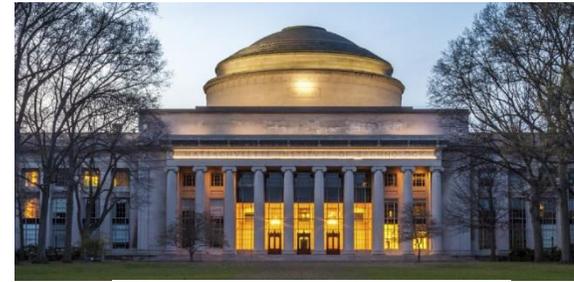
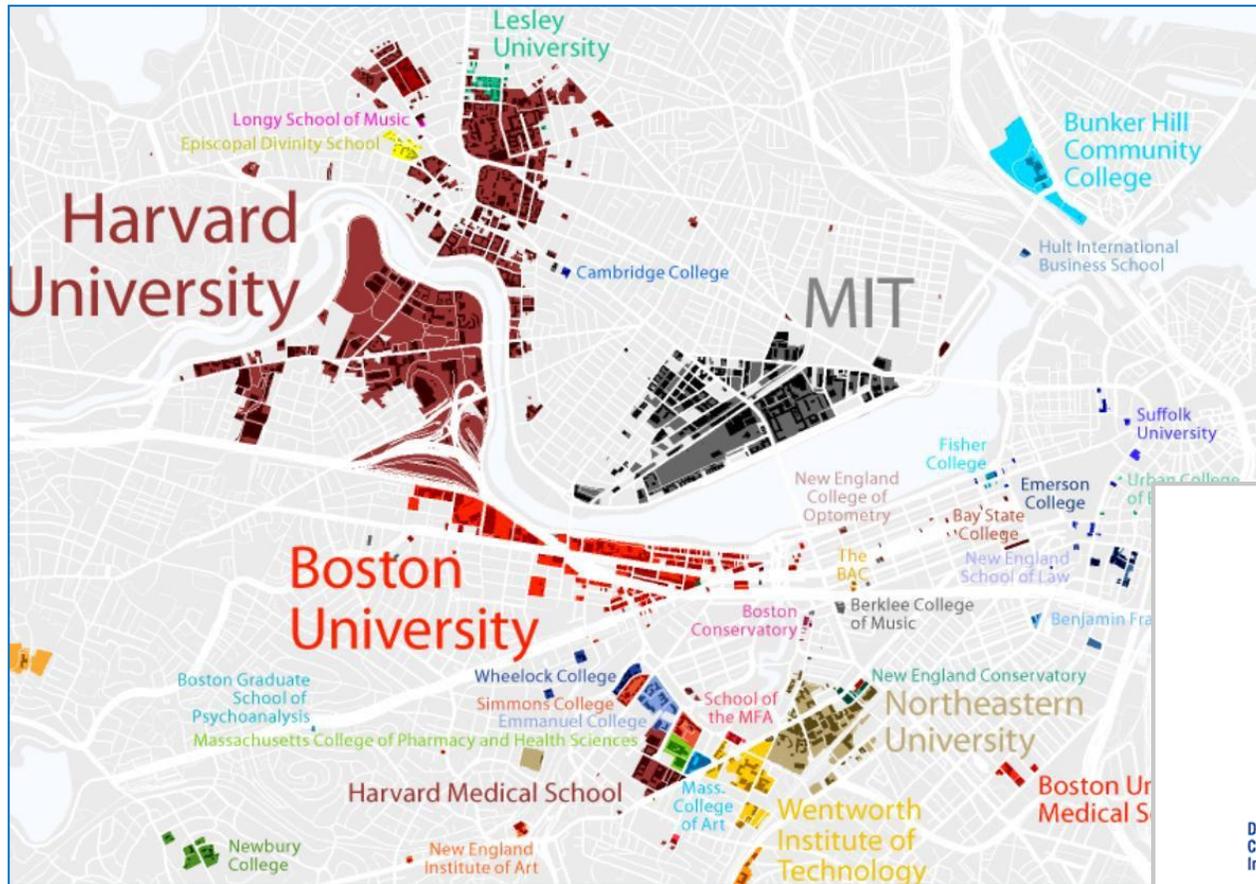
- 2022 -
World's first porcine-to-human heart transplantation

Cardiology's Digital Transformation:

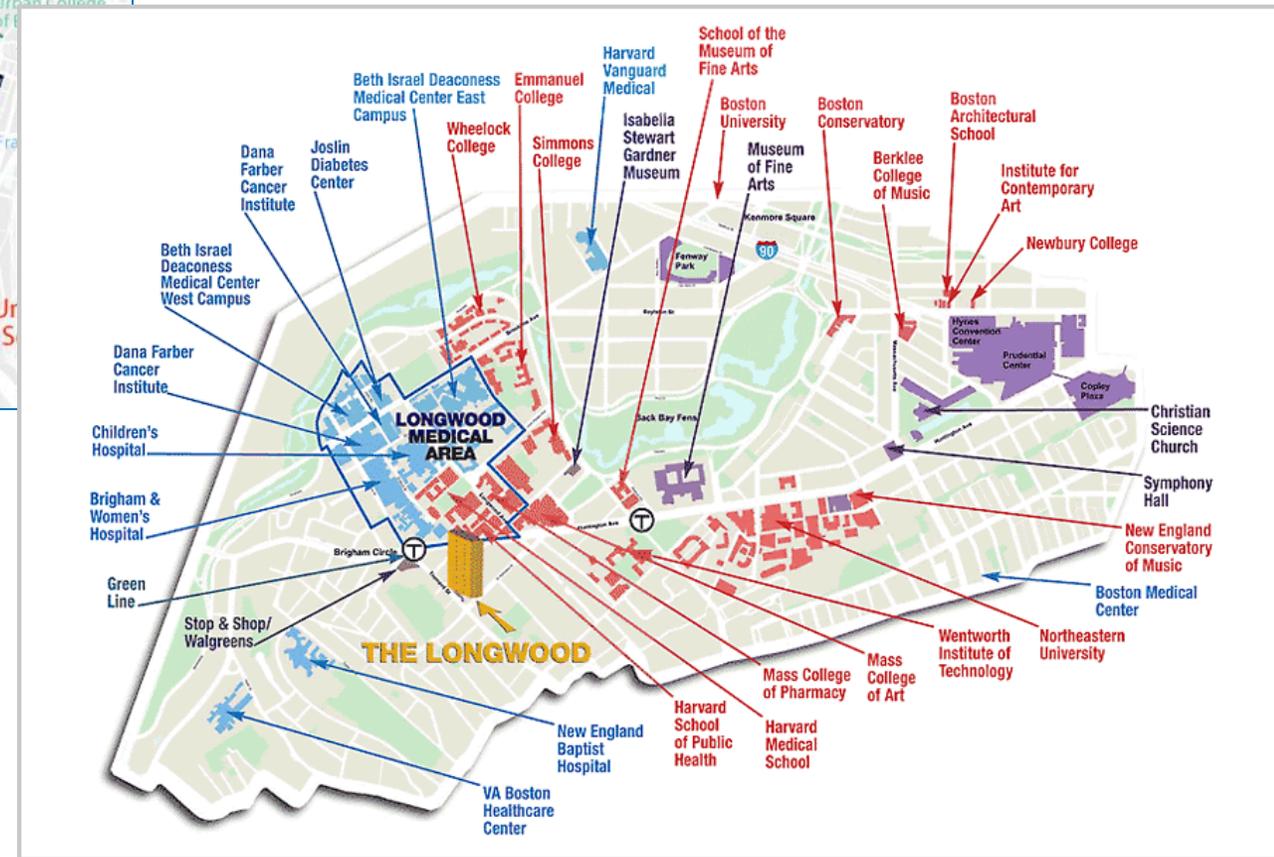
Technology-Enabled Collaboration Across the Health Care Ecosystem

Reducción de mortalidad CV en relación a los avances científicos





MIT Massachusetts Institute of Technology



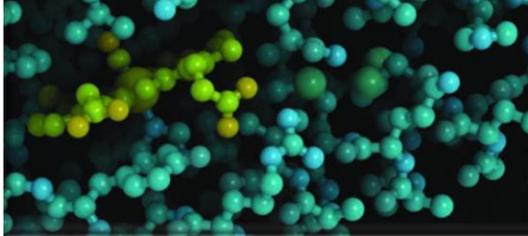
Convergence: The Future of Health



MIT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Third Revolution:

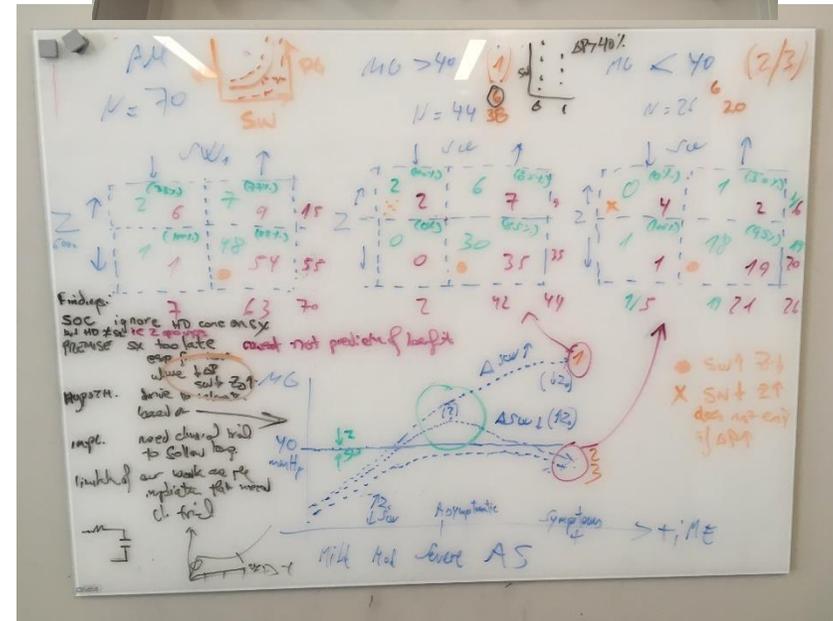
The Convergence of
the **Life Sciences**,
Physical Sciences,
and **Engineering**



A strategy for “convergence” research to transform
biomedicine

Report calls for more integration of physical, life sciences for needed advances in
biomedical research.

PhD, PostDoc, grad., undergrad.,,,,,,
 Eng Mech, Eng Biotech, Eng Computat
 Cardiologist, Interventional Cardiologist,
 Stats, Maths,





Max Olender

Computational Processing and Modeling of Intravascular Images

1384

IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 38, NO. 6, JUNE 2019



A Mechanical Approach for Smooth Surface Fitting to Delineate Vessel Walls in Optical Coherence Tomography Images

Max L. Olender¹, Member, IEEE, Lambros S. Athanasiou², Member, IEEE, José M. de la Torre Hernández, Eyal Ben-Assa, Farhad Rikhtegar Nezami³, and Elazer R. Edelman

Estimating the Internal Elastic Membrane Cross-Sectional Area of Coronary Arteries Autonomously using Optical Coherence Tomography Images*

Max L. Olender, Member, IEEE, Lambros S. Athanasiou, José M. de la Torre Hernández, Tamara García Camarero, José D. Cascón, Luciano Consuegra-Sanchez, and Elazer R. Edelman

Artificially synthesized optical coherence tomography images based on intravascular ultrasound-virtual histology examination of diseased coronary artery

Supported by the EuroIntervention Journal

Intravascular imaging is a cornerstone of invasive management of coronary disease, requiring specialized training to interpret either IVUS or OCT. AI can facilitate interpretation by non-specialists in real time.

EuroIntervention

Authors

[Max L. Olender](#)^{1,2}, [José M. de la Torre Hernández](#)³, [Farhad R. Nezami](#)^{1,4}, [Elazer R. Edelman](#)^{1,5}

ACCEPTED MANUSCRIPT

Translational Challenges for Synthetic Imaging in Cardiology

Max L Olender, Ph.D , Farhad R Nezami, Ph.D, Lambros S Athanasiou, Ph.D, José M de la Torre Hernández, M.D., Ph.D., F.E.S.C, Elazer R Edelman, M.D., Ph.D., F.A.C.C

European Heart Journal - Digital Health, ztab079,



Zahra Motamed

Computational Processing and Cardiovascular Physiology

ORIGINAL RESEARCH

Mixed Valvular Disease Following Transcatheter Aortic Valve Replacement: Quantification and Systematic Differentiation Using Clinical Measurements and Image-Based Patient-Specific In Silico Modeling

Zahra Keshavarz-Motamed, PhD; Seyedvahid Khodaei, MS; Farhad Rikhtegar Nezami, PhD; Junedh M. Amrute, BS; Suk Joon Lee, BS; Jonathan Brown, BS; Eyal Ben-Assa, MD; Tamara Garcia Camarero, MD; Javier Ruano Calvo, MD; Stephanie Sellers, MD; Philipp Blanke, MD; Jonathon Leipsic, MD; Jose M. de la Torre Hernandez, MD, PhD; Elazer R. Edelman, MD, PhD



Effects of Choice of Medical Imaging Modalities on a Non-invasive Diagnostic and Monitoring Computational Framework for Patients With Complex Valvular, Vascular, and Ventricular Diseases Who Undergo Transcatheter Aortic Valve Replacement

OPEN ACCESS

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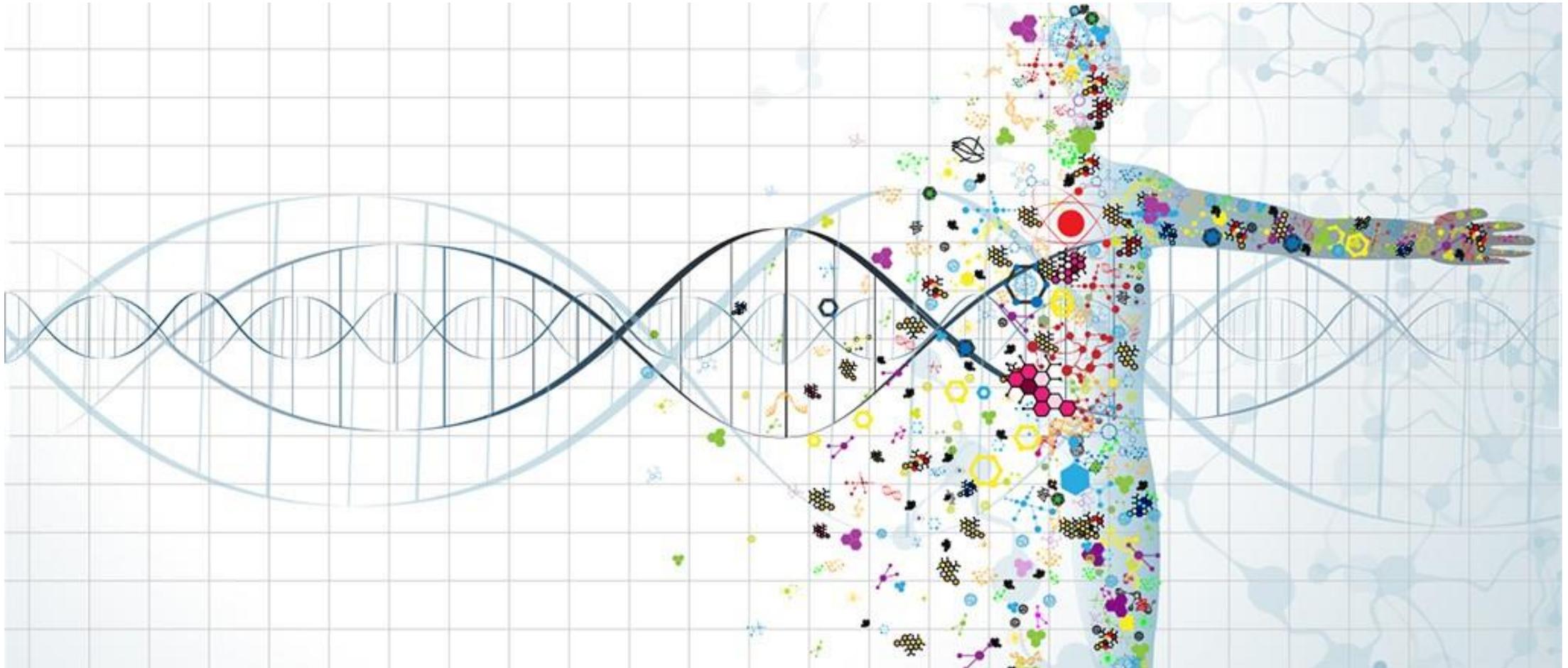
Melissa Baiocchi^{1†}, Shirley Barsoum^{1†}, Seyedvahid Khodaei¹,
Jose M. de la Torre Hernandez², Sydney E. Valentino³, Emily C. Dunford³,
Maureen J. MacDonald³ and Zahra Keshavarz-Motamed^{1,4,5*}

¹ Department of Mechanical Engineering, McMaster University, Hamilton, ON, Canada, ² Hospital Universitario Marques de Valdecilla, IDIVAL, Santander, Spain, ³ Department of Kinesiology, McMaster University, Hamilton, ON, Canada, ⁴ School of Biomedical Engineering, McMaster University, Hamilton, ON, Canada, ⁵ School of Computational Science and Engineering, McMaster University, Hamilton, ON, Canada

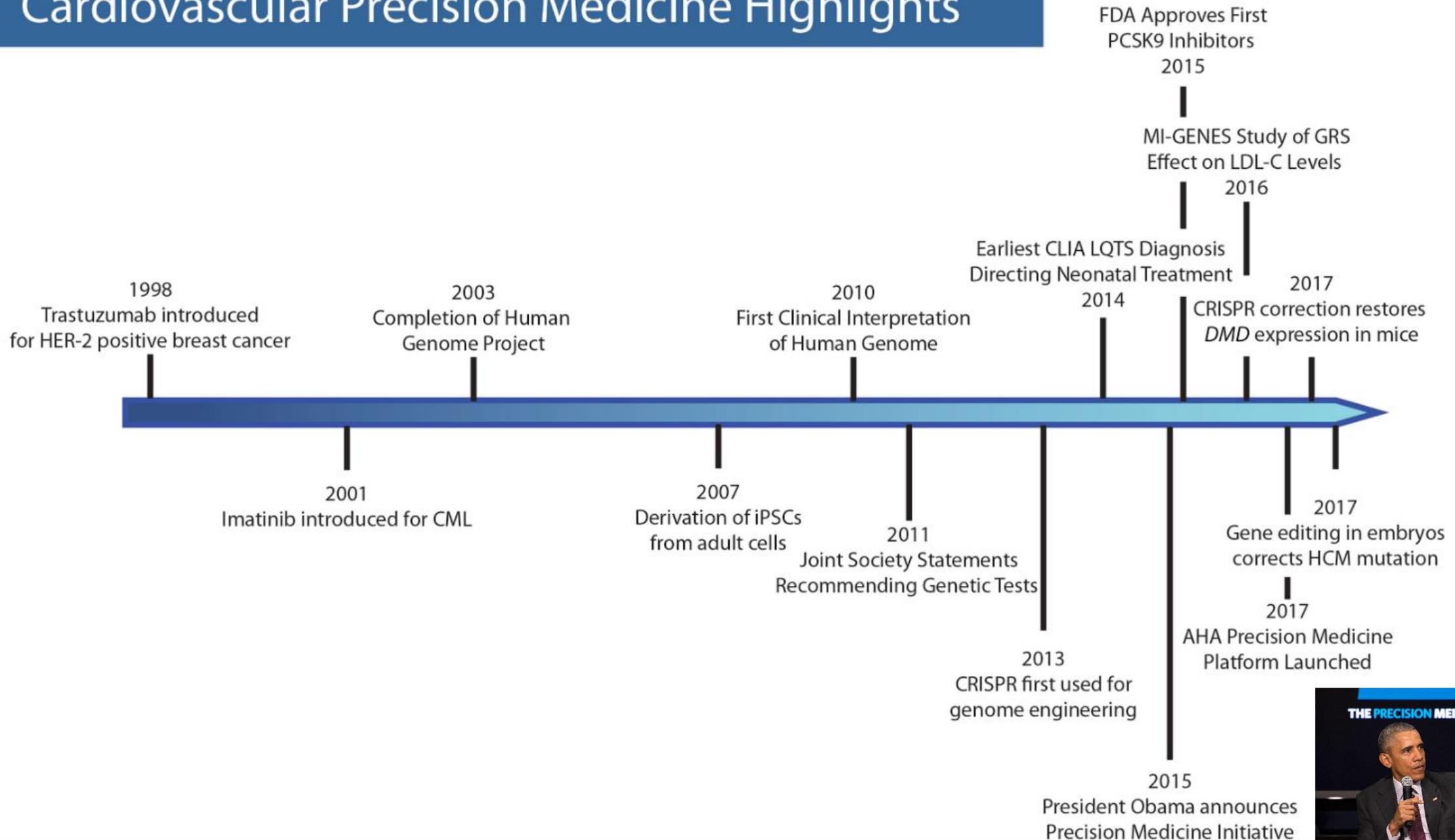


Medicina de precisión:

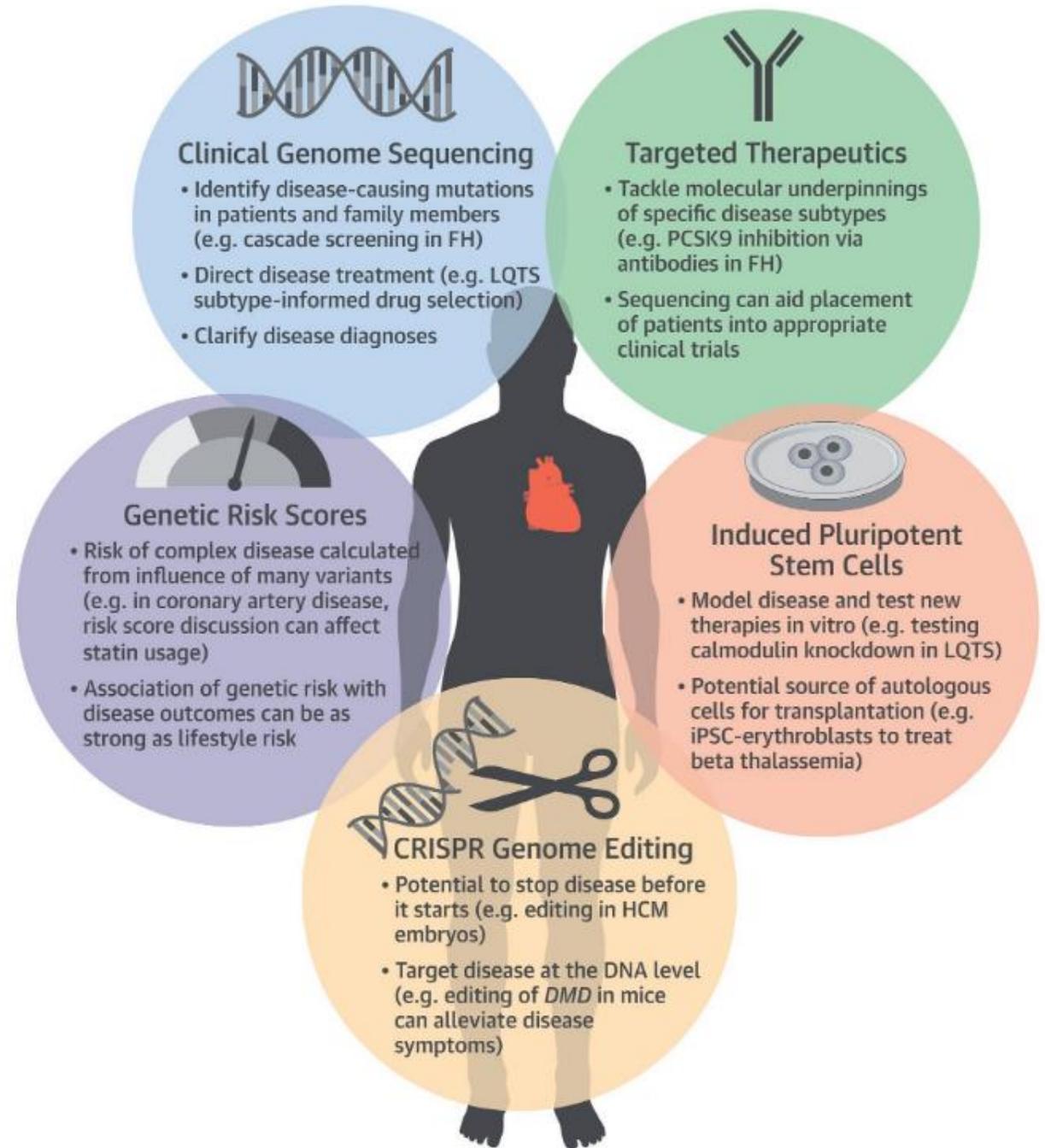
Adaptar el tratamiento a cada persona.



Cardiovascular Precision Medicine Highlights

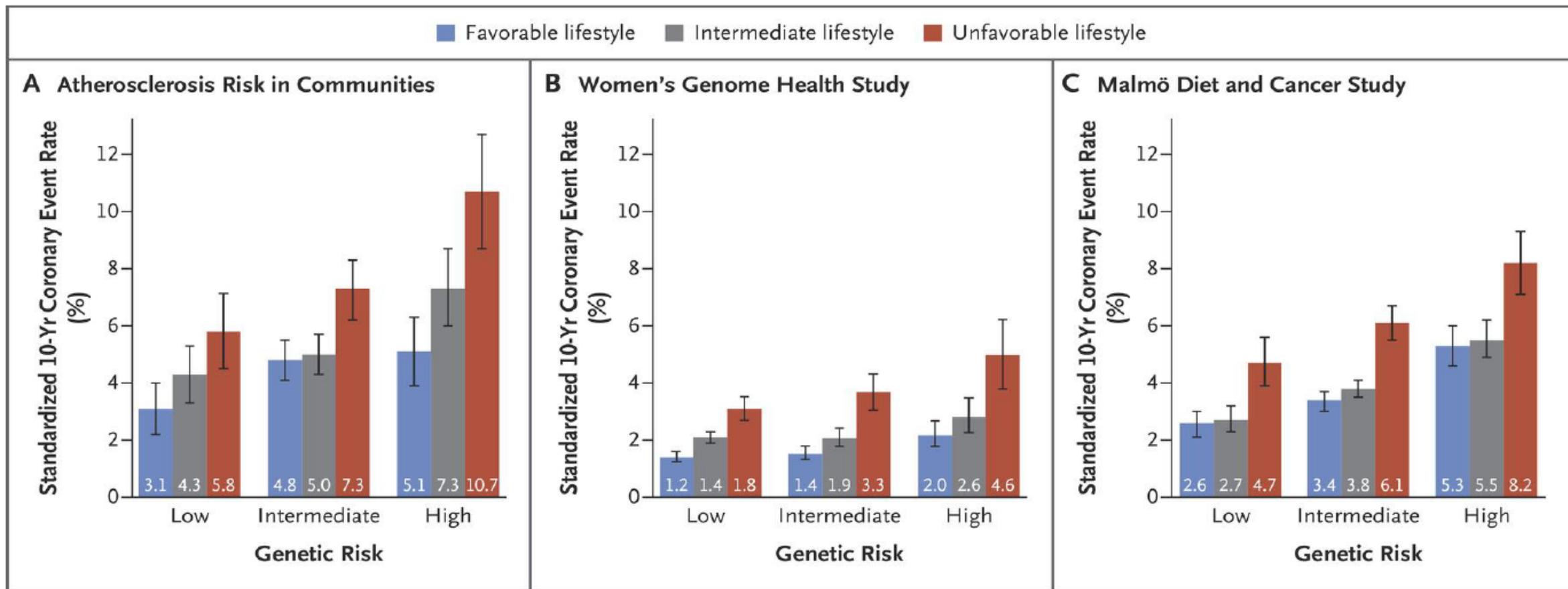


Las tecnologías genéticas están revolucionando la medicina de precisión



Riesgo genético y estilo de vida

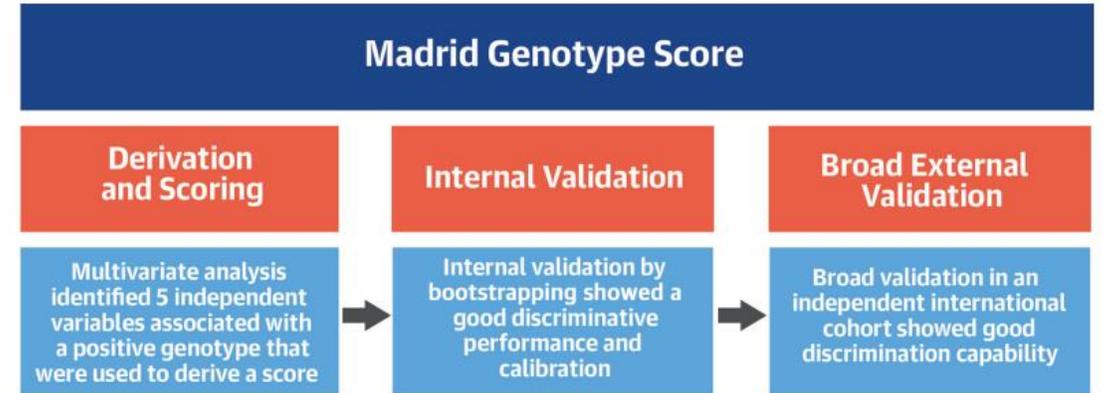
- ~50K participants from 3 studies
- Polygenic risk score developed from 50 SNPs associated with CAD
- Healthy lifestyle defined by tobacco use, obesity, diet, physical activity



Clinical Risk Score to Predict Pathogenic Genotypes in Patients With Dilated Cardiomyopathy



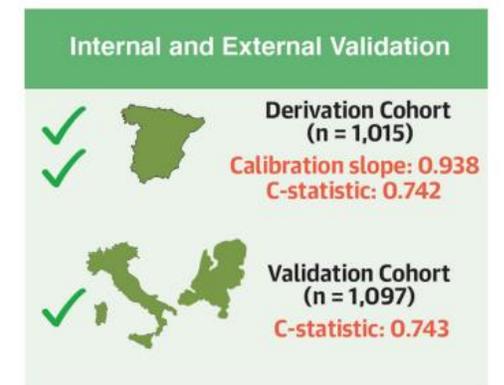
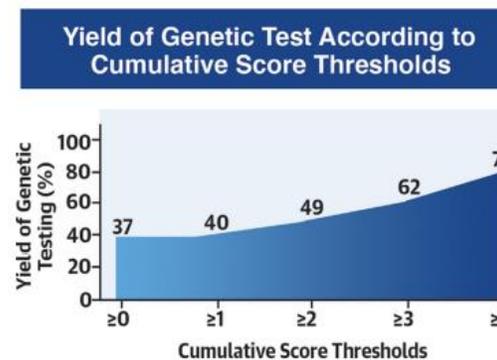
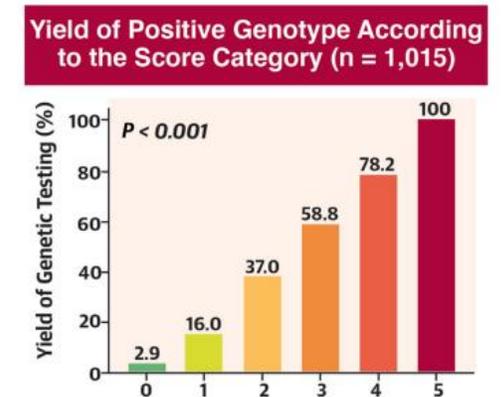
Luis Escobar-Lopez, MD,^{a,b,c} Juan Pablo Ochoa, MD, PhD,^{a,c} Ana Royuela, PhD,^d Job A.J. Verdonschot, MD, PhD,^e Matteo Dal Ferro, MD,^{c,f} Maria Angeles Espinosa, MD, PhD,^{b,g} Maria Sabater-Molina, PhD,^{b,c,h} Maria Gallego-Delgado, MD, PhD,^{b,i} Jose M. Larrañaga-Moreira, MD,^{b,j} Jose M. Garcia-Pinilla, MD, PhD,^{b,k} Maria Teresa Basurte-Elorz, MD,^l José F. Rodríguez-Palomares, MD, PhD,^{b,m} Vicente Climent, MD,ⁿ Francisco J. Bermudez-Jimenez, MD, PhD,^o María Victoria Mogollón-Jiménez, MD,^p Javier Lopez, MD, PhD,^{b,q} Maria Luisa Peña-Peña, MD,^r Ana Garcia-Alvarez, MD, PhD,^{b,s,t} Bernardo López-Abel, MD,^{b,u} Tomas Ripoll-Vera, MD, PhD,^v Julian Palomino-Doza, MD, PhD,^{b,w} Antoni Bayes-Genis, MD, PhD,^{b,x} Ramon Brugada, MD, PhD,^{b,y} Uxua Idiazabal, MD,^z Jesus G. Mirelis, MD, PhD,^{a,b,c} Fernando Dominguez, MD, PhD,^{a,b,c} Michiel T.H.M. Henkens, MD,^{aa} Ingrid P.C. Krapels, MD, PhD,^e Han G. Brunner, MD, PhD,^{e,bb,cc} Alessia Paldino, MD,^{c,f} Denise Zaffalon, MD,^{c,f} Luisa Mestroni, MD,^{dd} Gianfranco Sinagra, MD,^{c,f} Stephane R.B. Heymans, MD, PhD,^{aa,ee} Marco Merlo, MD,^{c,f} Pablo Garcia-Pavia, MD, PhD^{a,b,c,ff}



Predictors of a Positive Genetic Result

Clinical Predictors	Points
Skeletal myopathy	1
Family history of DCM	1
Low voltage on ECG	1
Absence of hypertension	1
Absence of LBBB	1

Scoring Range: 0 to 5 Points



Serum and genetic markers related to rapid clinical progression of coronary artery disease



2023



Tamara García-Camarero,^{a,*} Sara Remuzgo-Martínez,^b Fernanda Genre,^b Raquel López-Mejías,^b Verónica Pulito-Cueto,^b Gabriela Veiga,^a Dae-Hyun Lee Hwang,^a Fermín Sáinz Laso,^a Aritz Gil Ongay,^a Miguel Ángel González-Gay,^{c,d} and José M. de la Torre Hernández^a

^aDepartamento de Cardiología, Hospital Universitario Marqués de Valdecilla, Instituto de Investigación Valdecilla, Santander, Cantabria, Spain

^bInstituto de Investigación Valdecilla, Santander, Cantabria, Spain

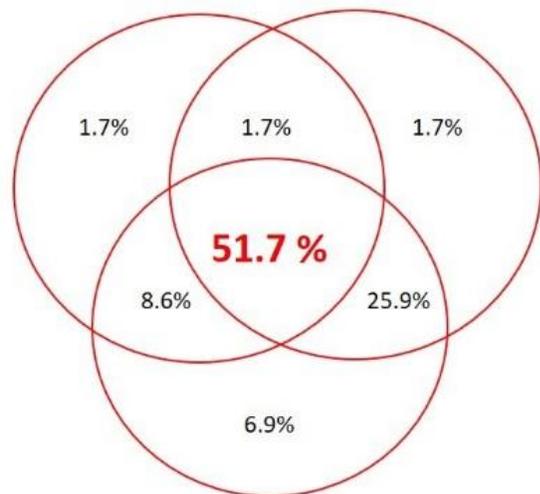
^cDepartamento de Medicina y Psiquiatría, Universidad de Cantabria, Santander, Cantabria, Spain

^dInstituto de Investigación Sanitaria-Fundación Jiménez Díaz, Madrid, Spain

RAPID CLINICAL PROGRESSOR

IL6 rs1800795 C allele

PCSK9 rs2483205 T allele

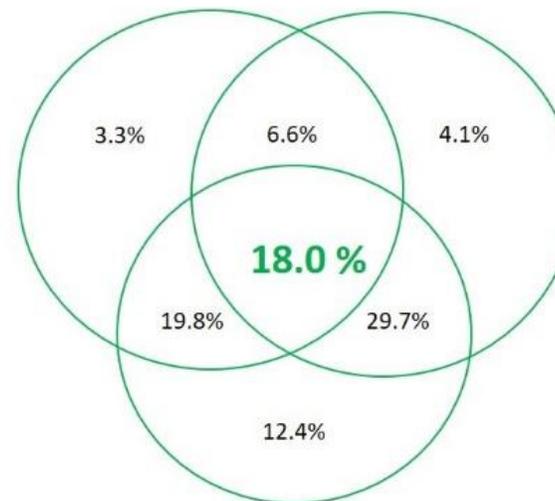


TNF rs3093664 non G allele

LONG STANDING STABLE

IL6 rs1800795 C allele

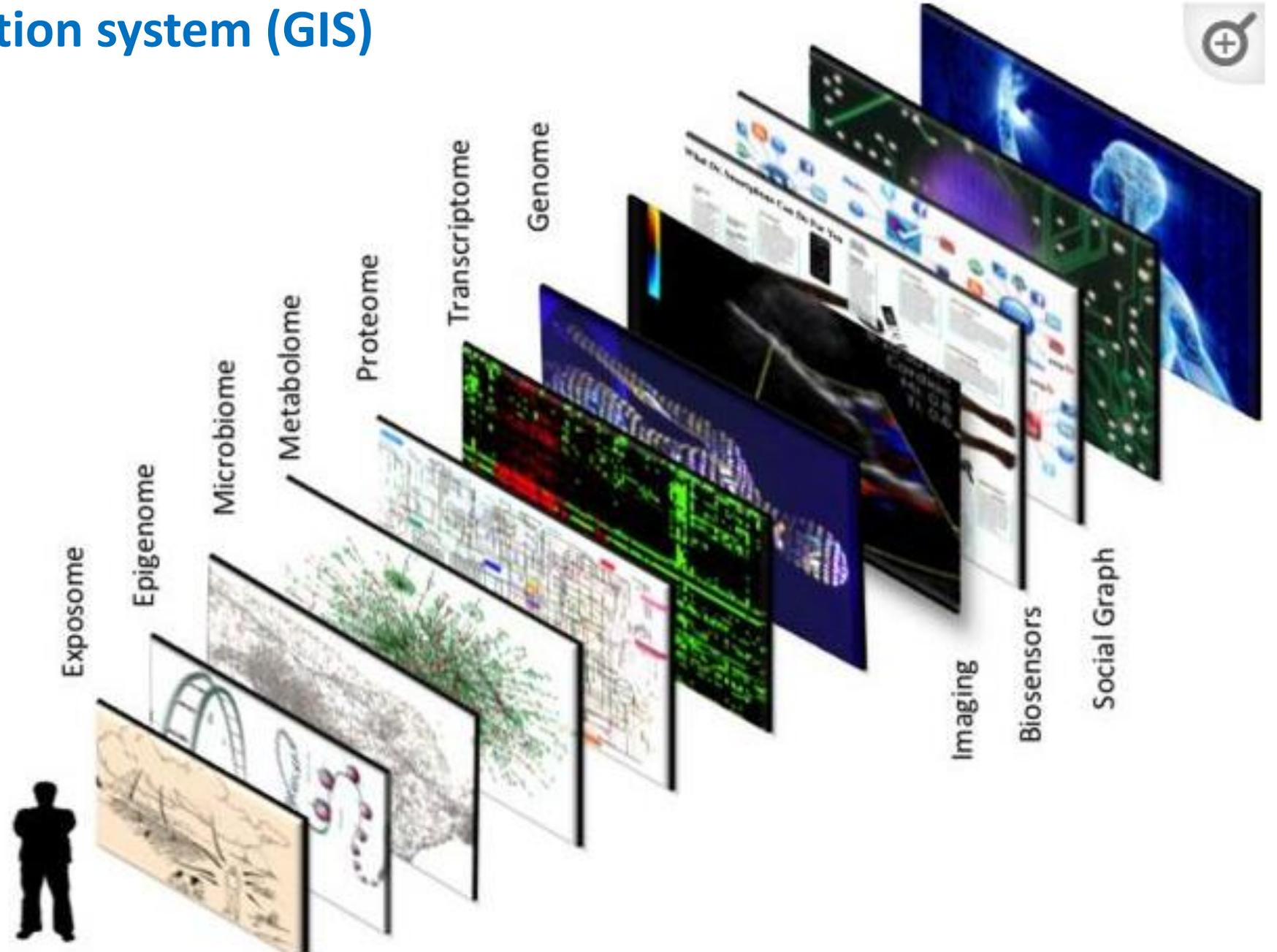
PCSK9 rs2483205 T allele



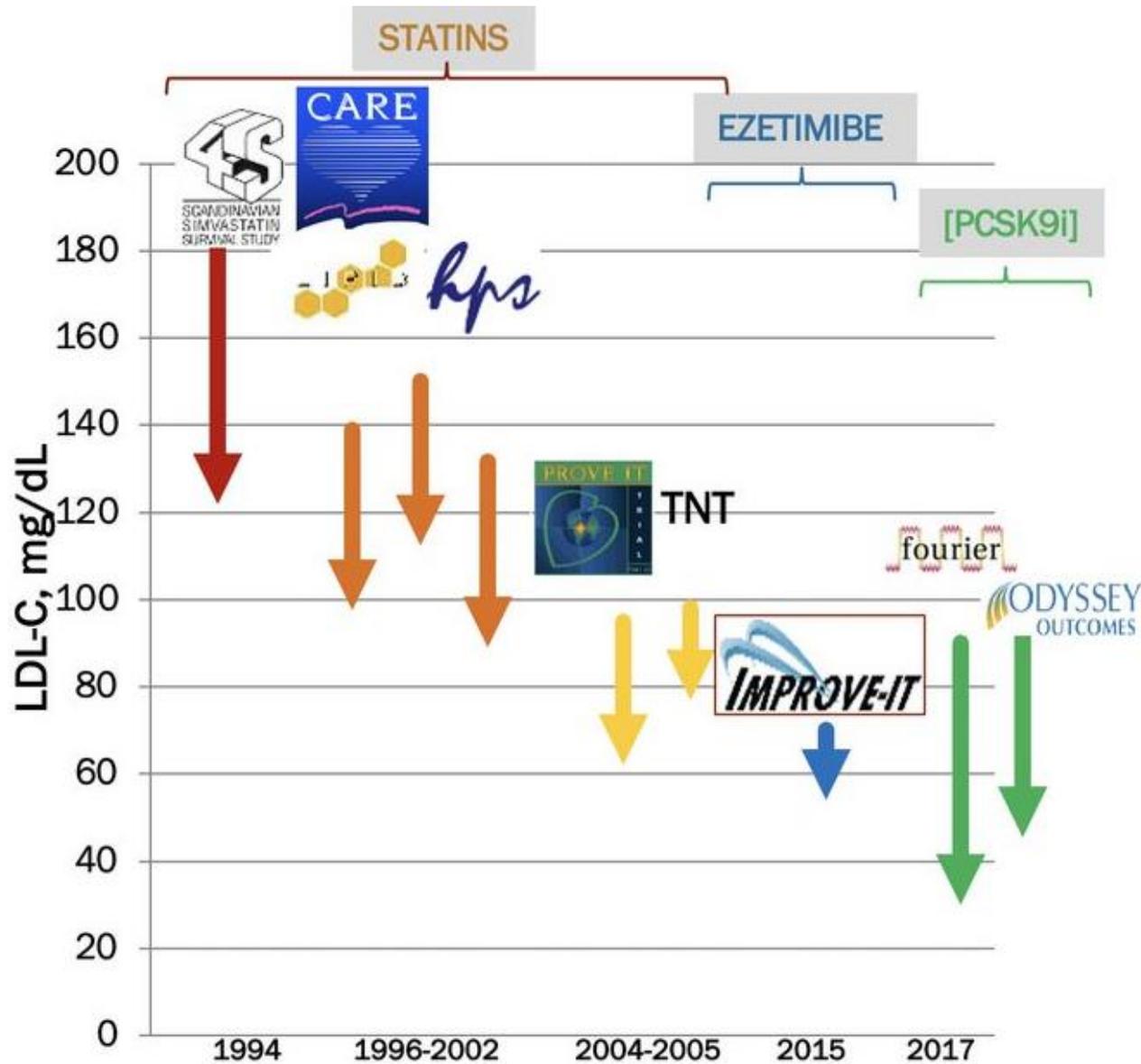
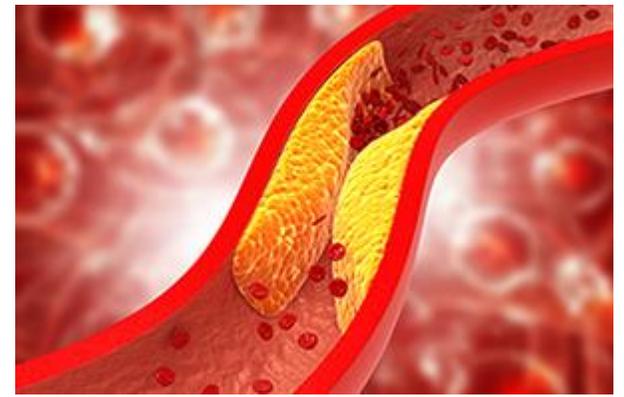
TNF rs3093664 non G allele

$p < 0.001$

Geographic information system (GIS) of a human being



LDL Cholesterol



High is bad

Average is not good

Lower is better

Even lower is even better

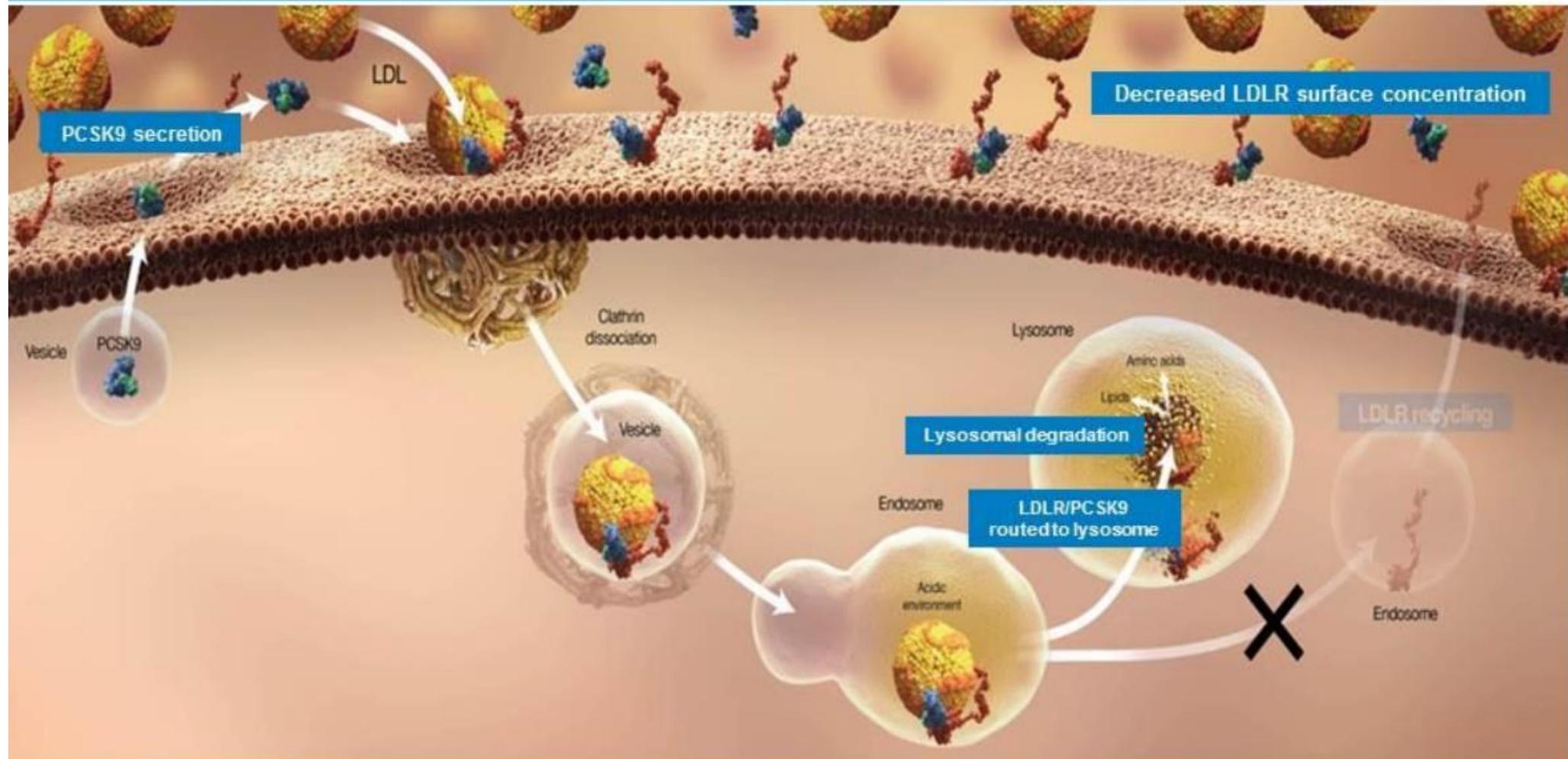
Lowest is best

Statins

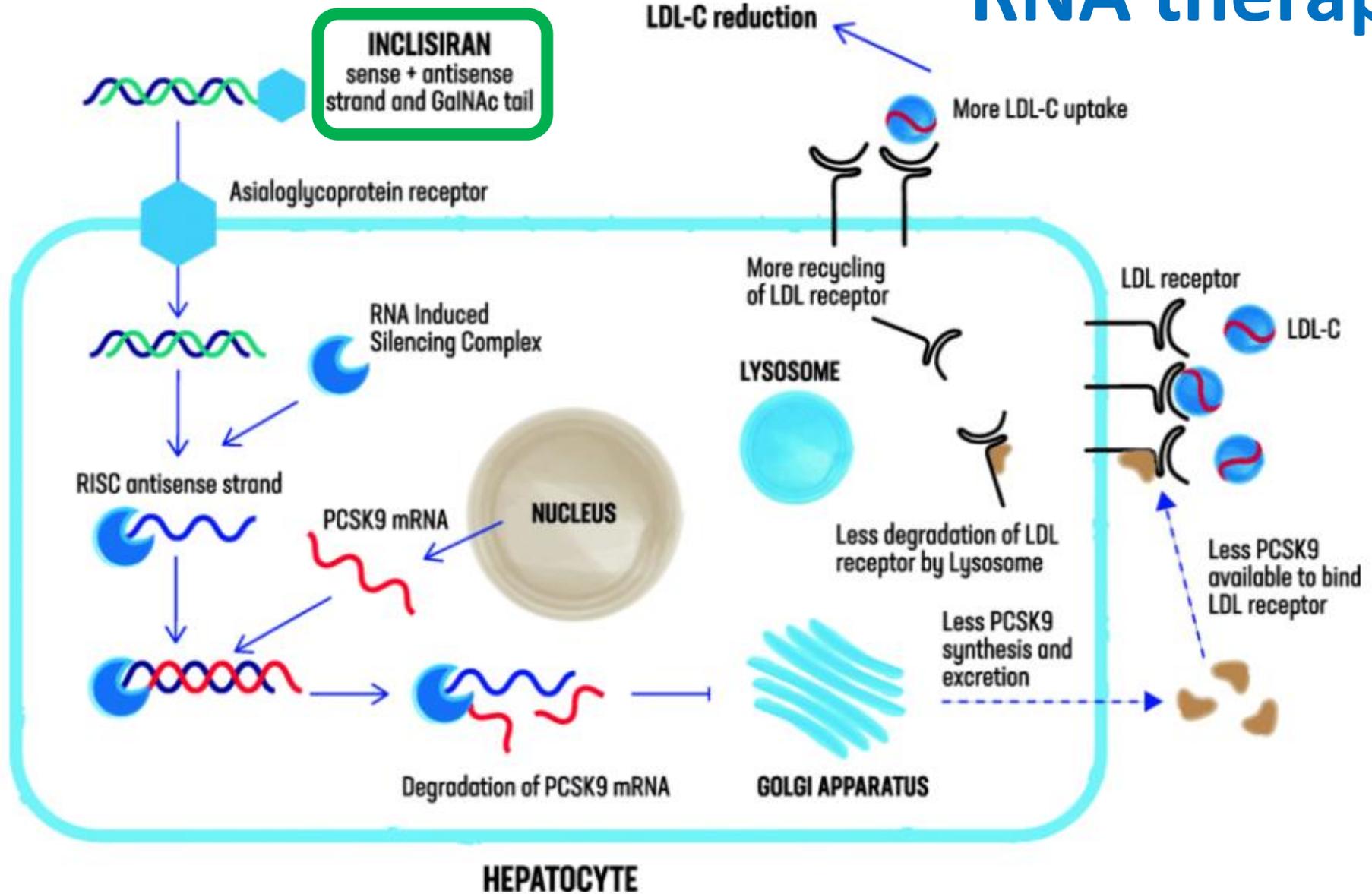
+ Ezetimibe

+ PCSK9I

PCSK9 Regulates the Surface Expression of LDLRs by Targeting for Lysosomal Degradation



RNA therapies

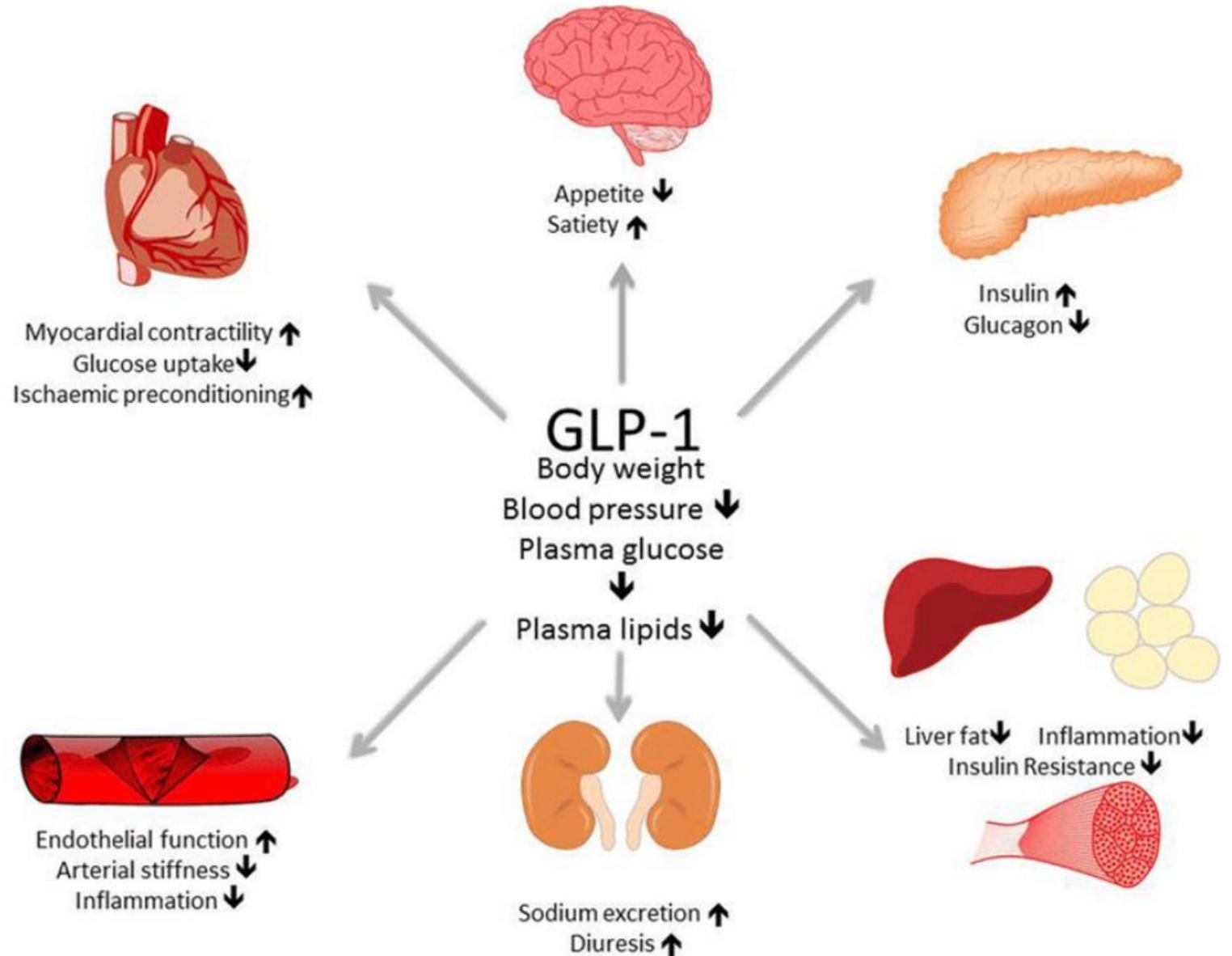


Los GLP-1

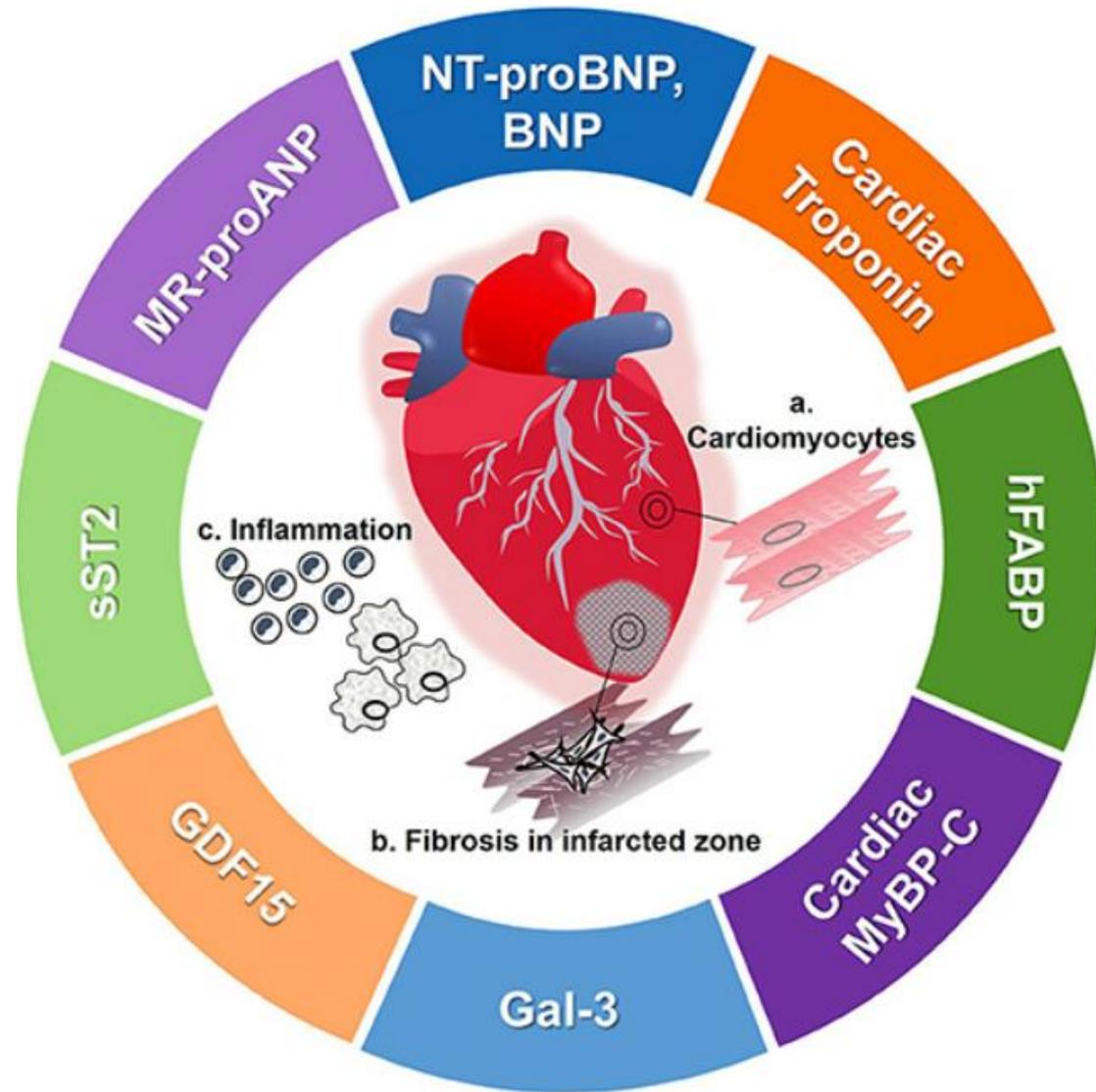
Control diabético

Reducción de peso

Reducción de eventos
cardiovasculares



Biomarcadores para definir pronóstico en la Insuficiencia Cardíaca (monitorización de respuesta a fármacos)



RETOS

Coste-efectividad, la privacidad de los datos, los marcos normativos y la formación de médicos y pacientes.

Accesibilidad a los fármacos mas novedosos y caros (equidad).

Mercado extra-sanitario de fármacos “atractivos” (Ozempic)

La **colaboración** entre profesionales sanitarios, investigadores, organismos reguladores y responsables políticos será clave.

Semaglutide



 Libertad Digital 

La cara de Ozempic: la transformación de los famosos que adelgazan con un fármaco para la diabetes

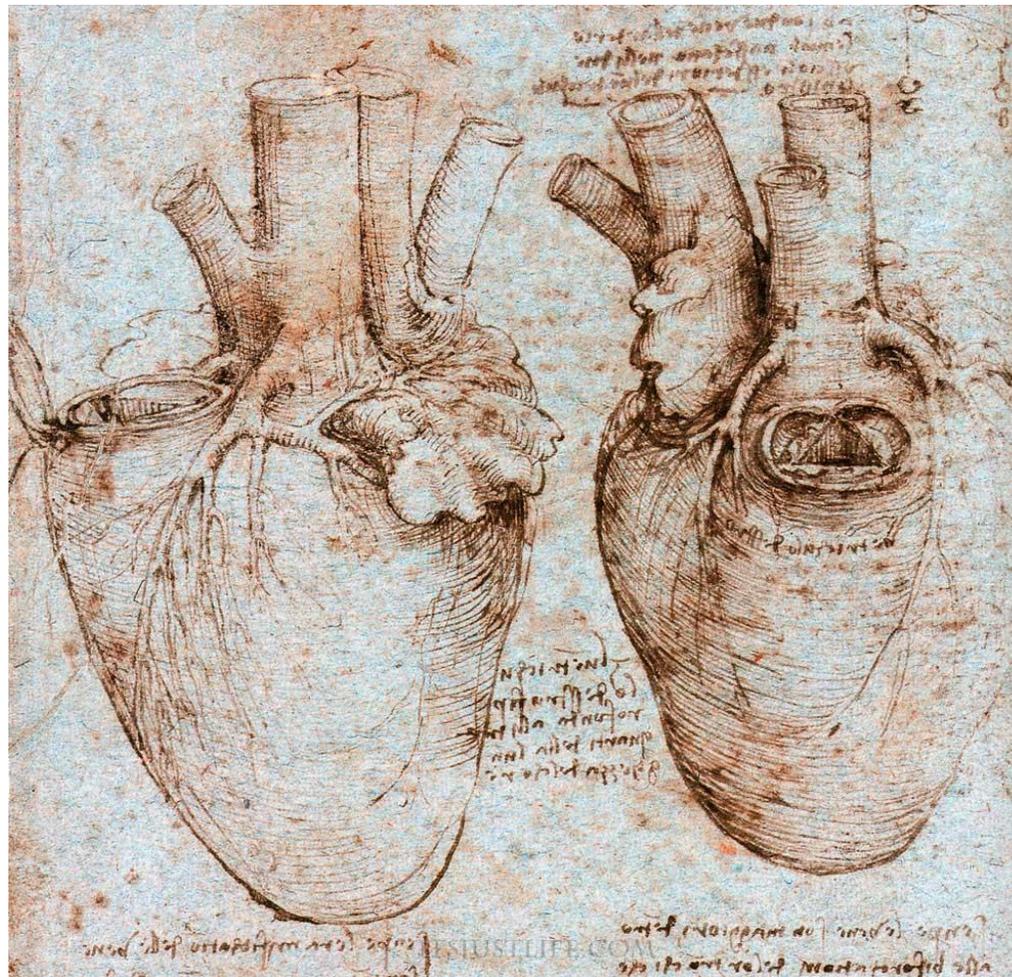
De sobra es conocida la obsesión de Hollywood por la imagen corporal y en los últimos años se ha puesto de moda administrarse Ozempic,...

1 month ago

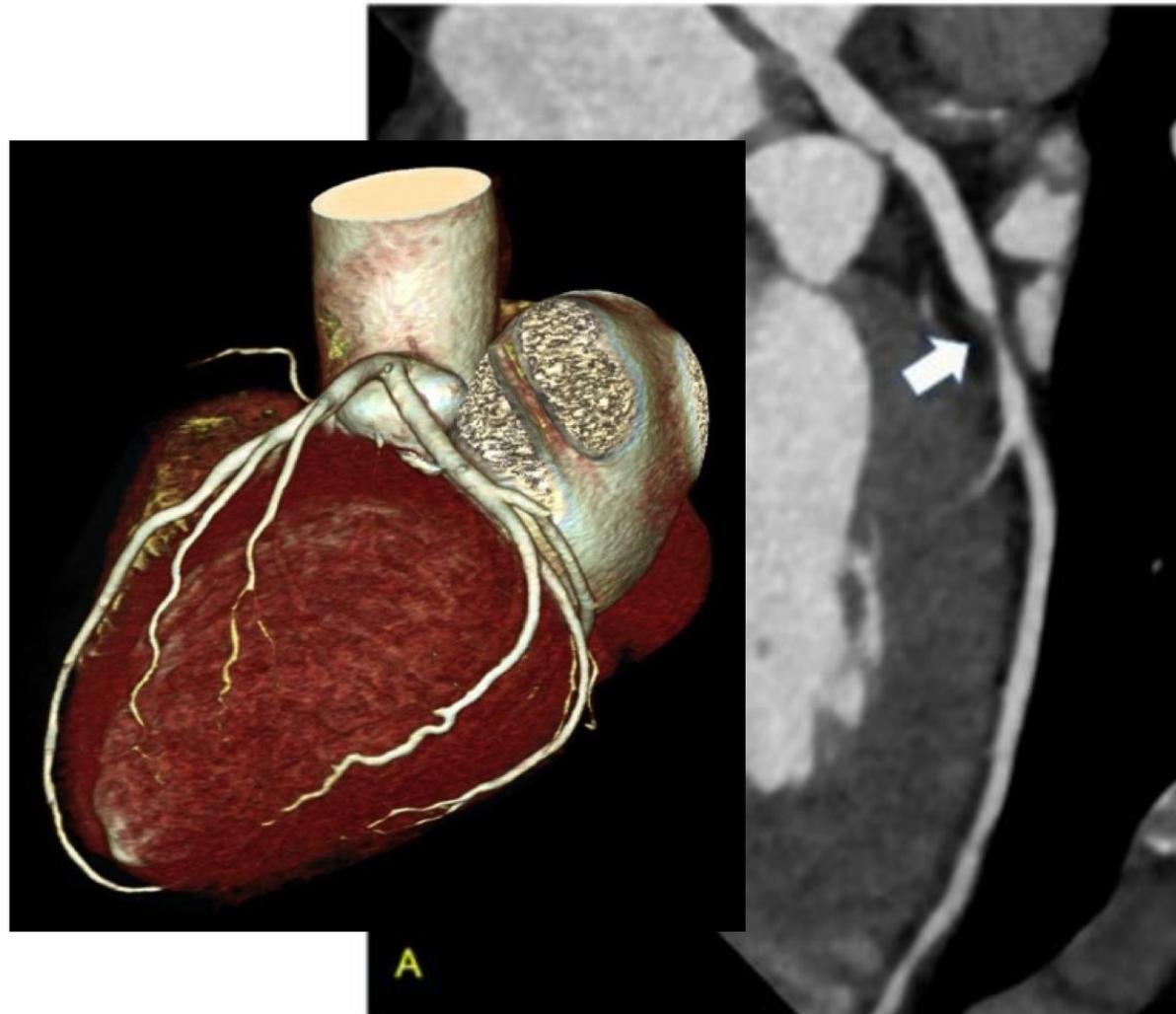


Tecnologías avanzadas de imagen:

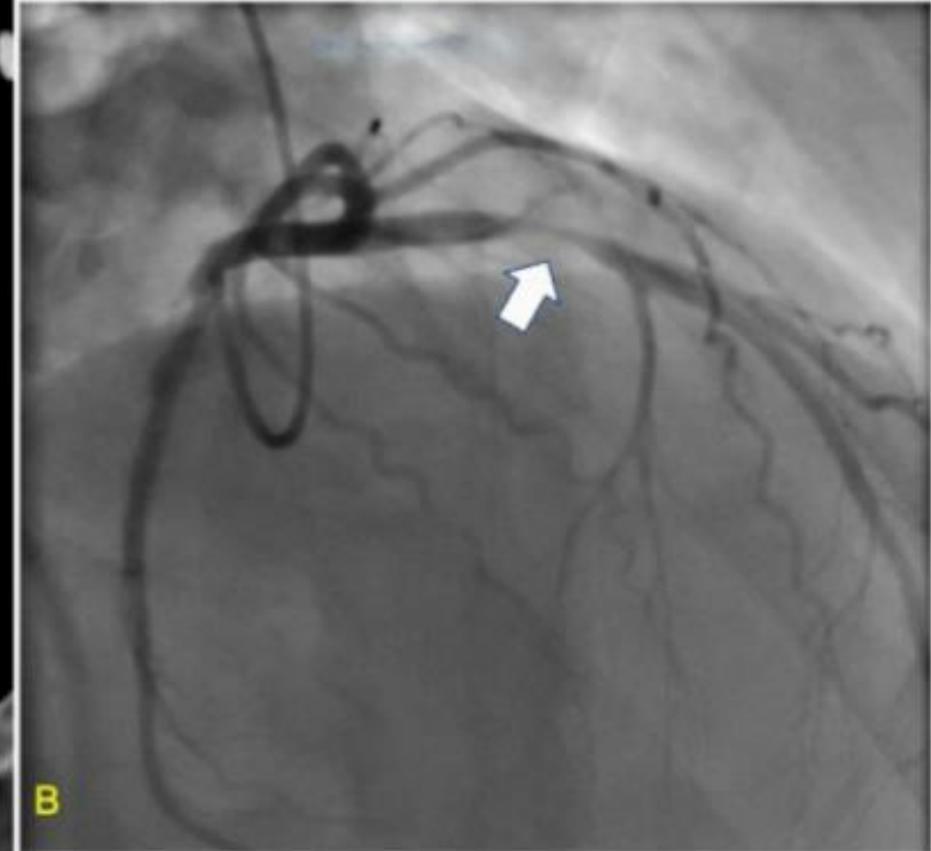
Visualización del corazón con un detalle sin precedentes



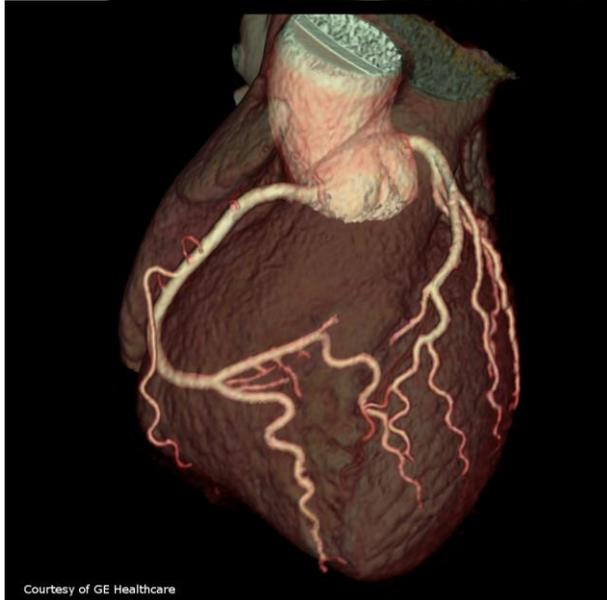
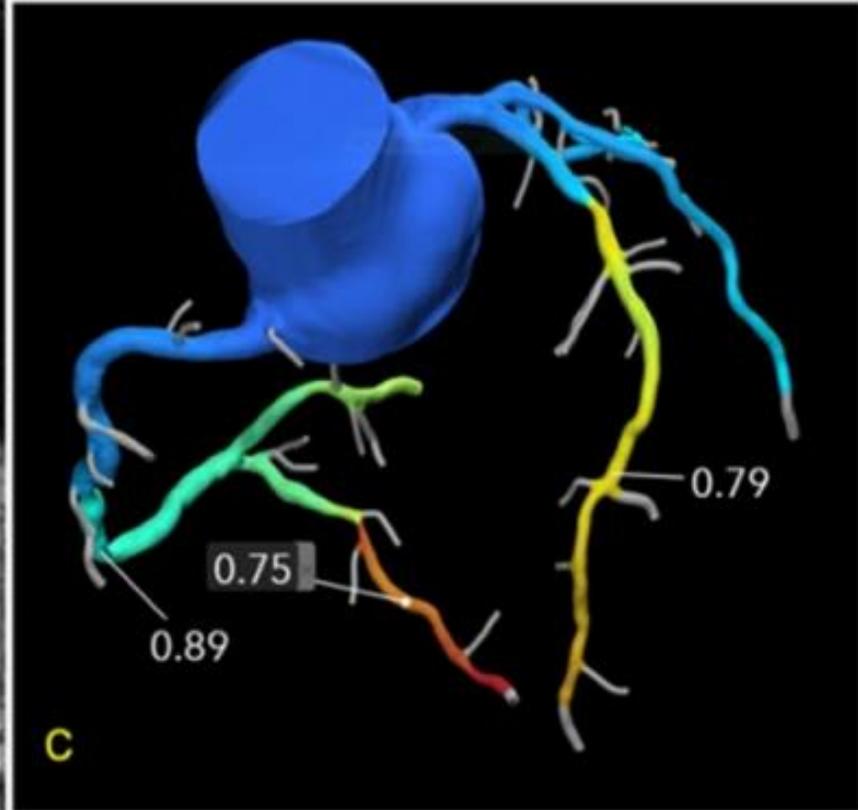
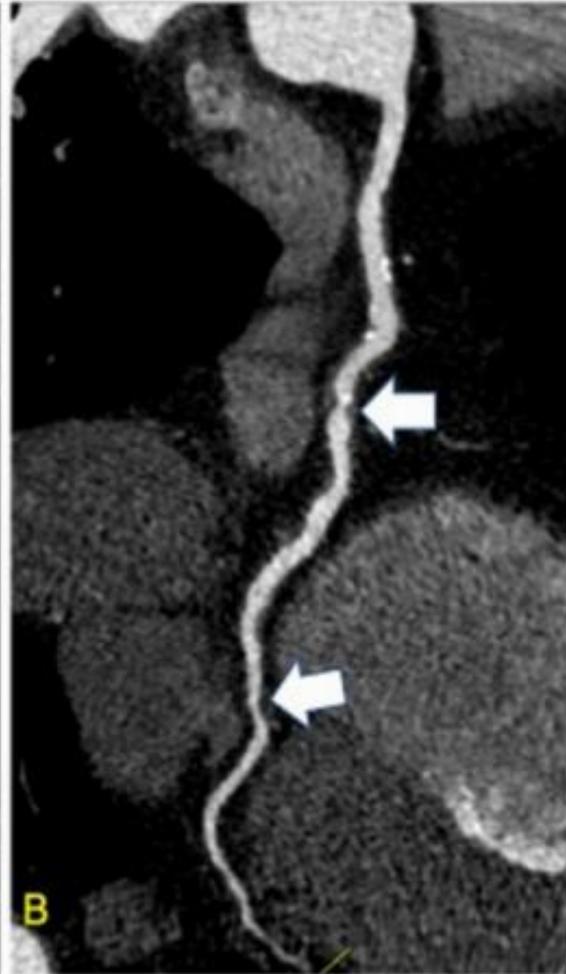
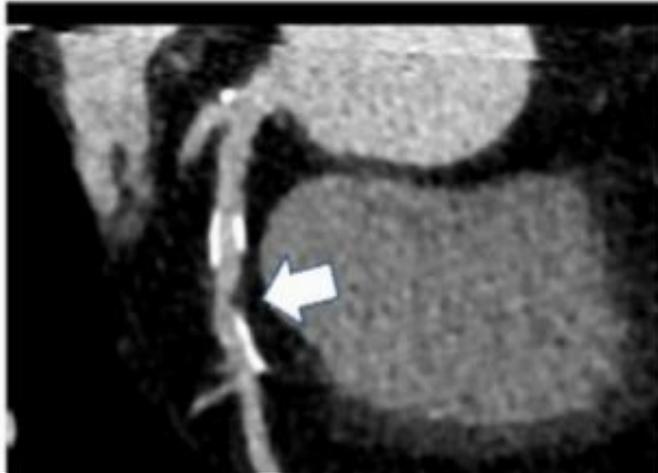
TAC



Cateterismo Coronariografia

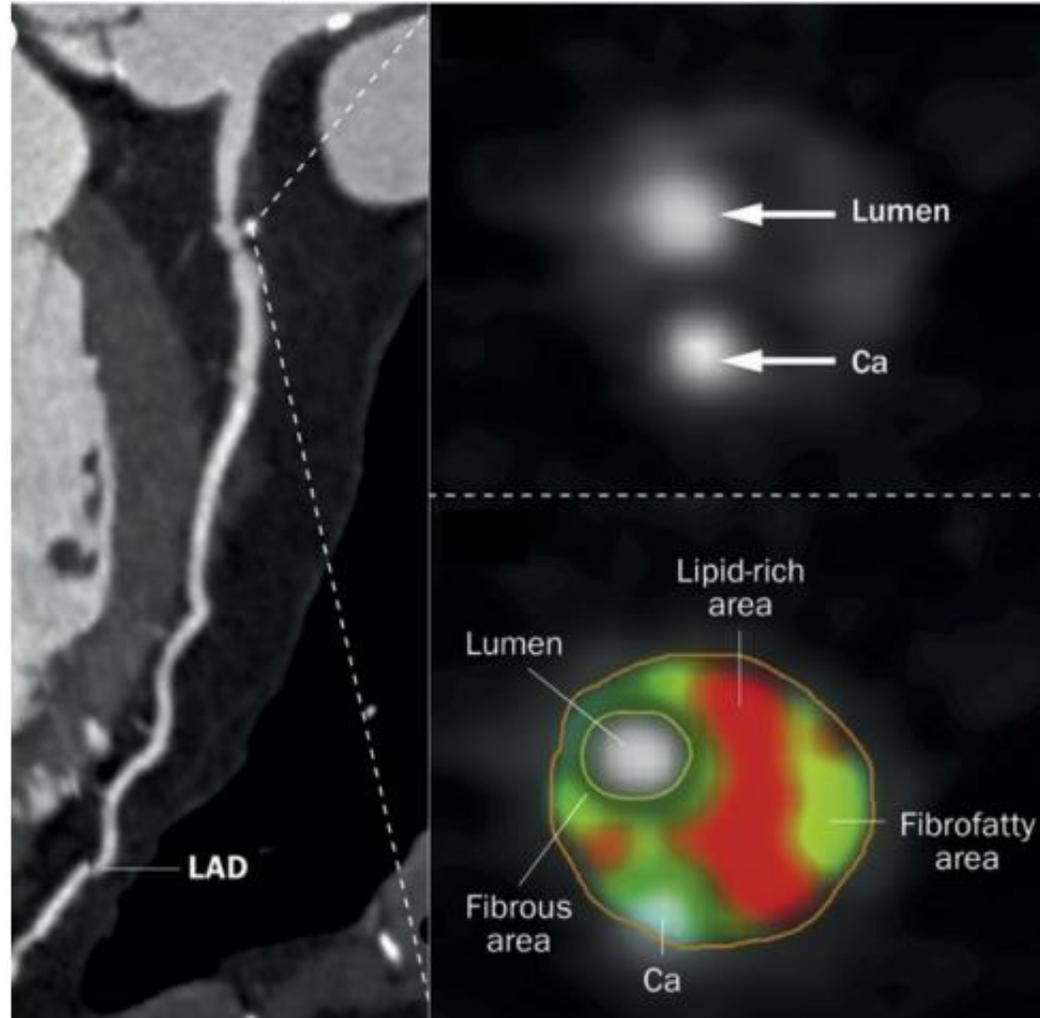


TAC: análisis cuantitativo de flujo coronario

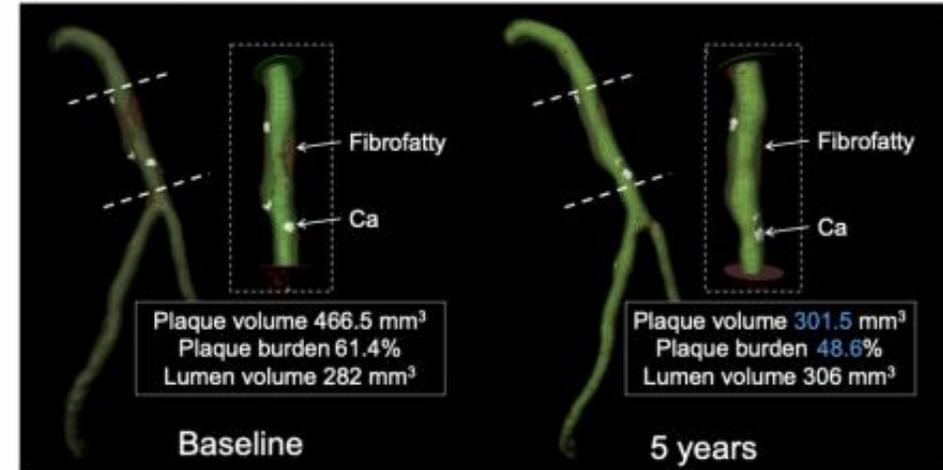


TAC: análisis composición de placa

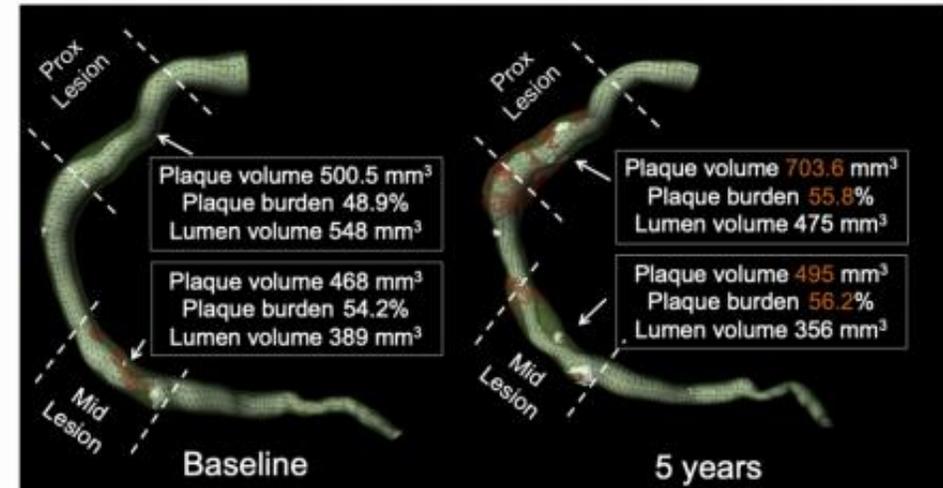
A Plaque analysis



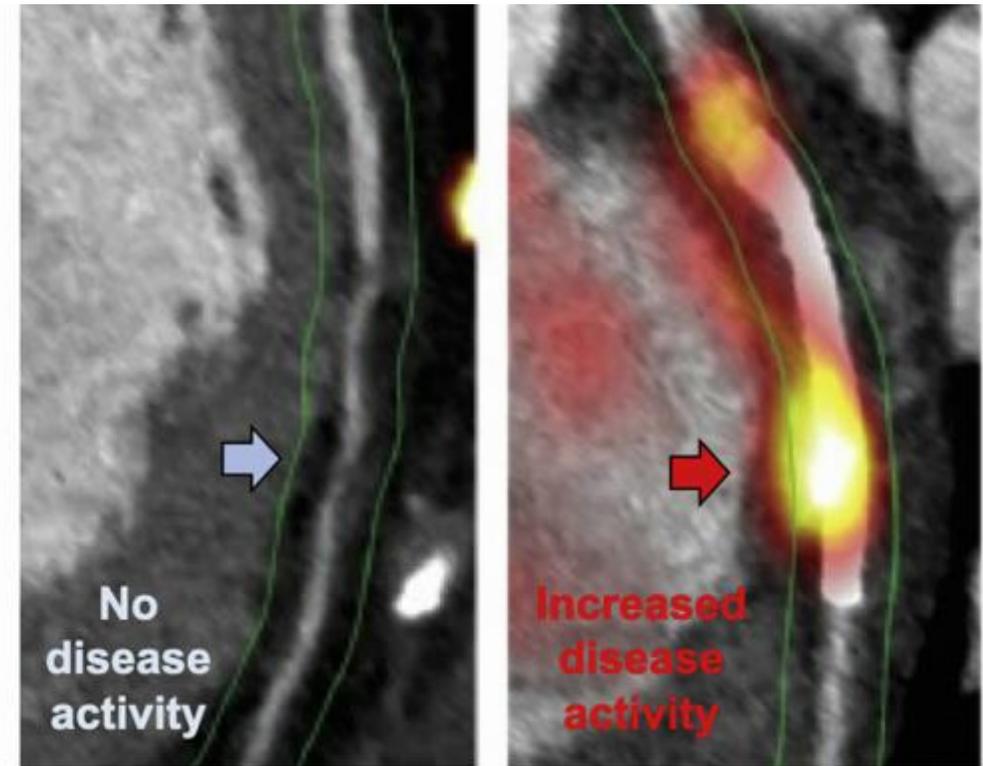
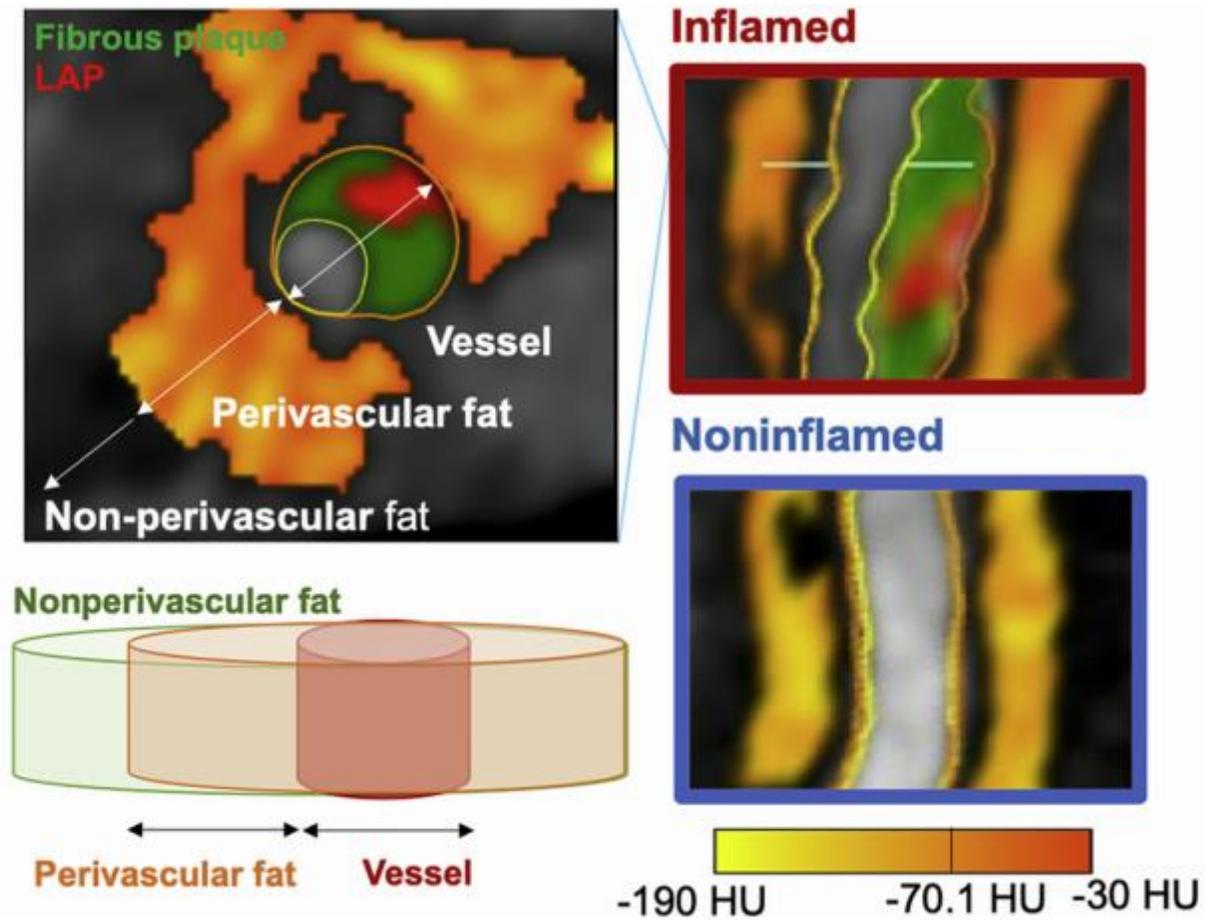
B Plaque regression



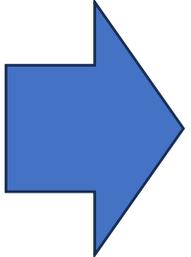
C Plaque progression



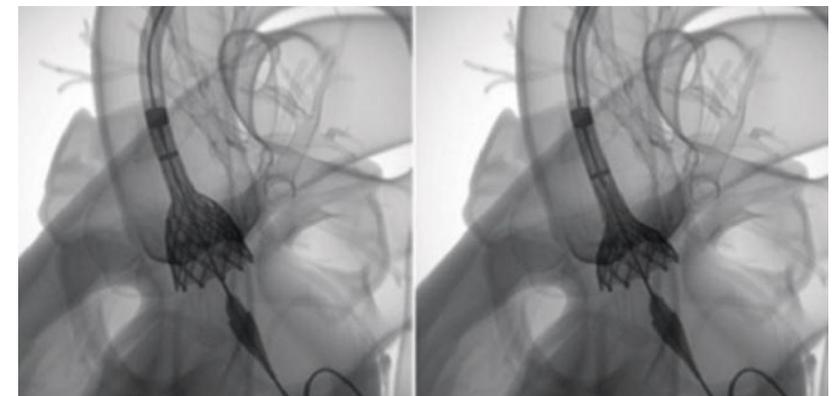
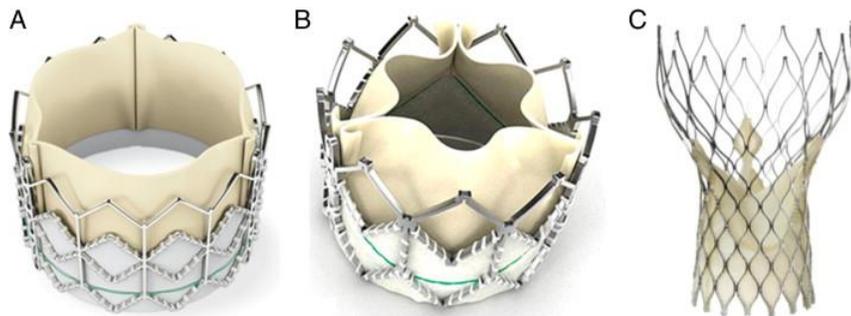
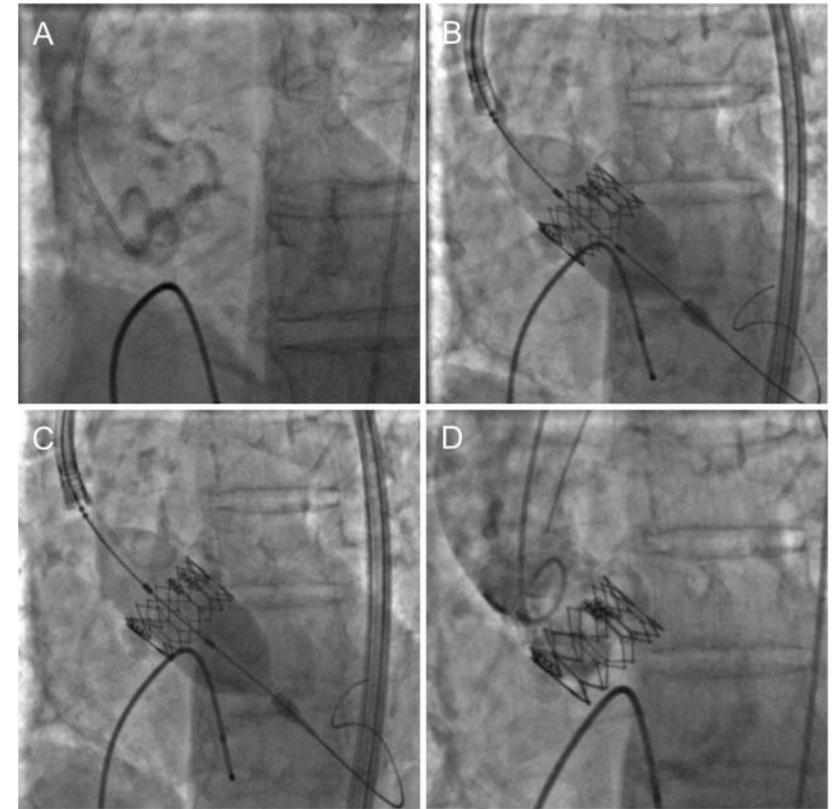
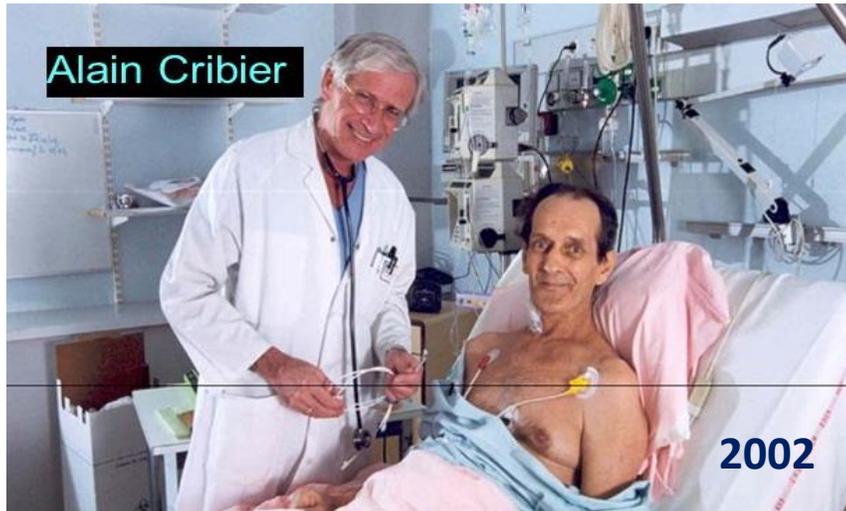
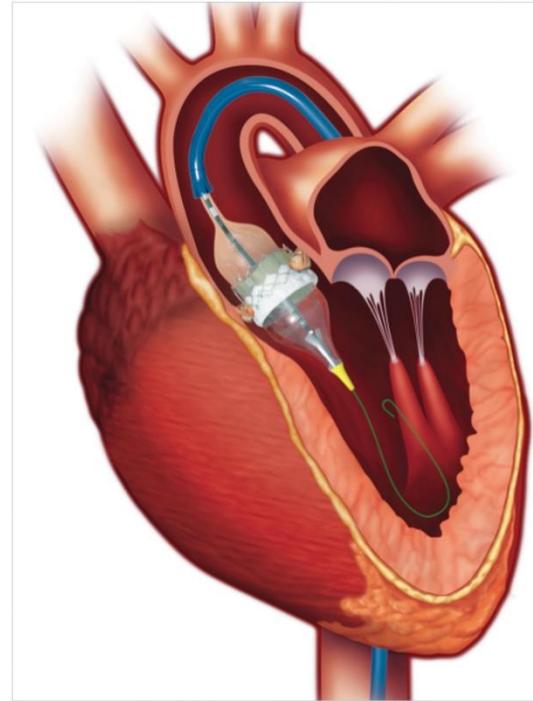
TAC: inflamación perivascular

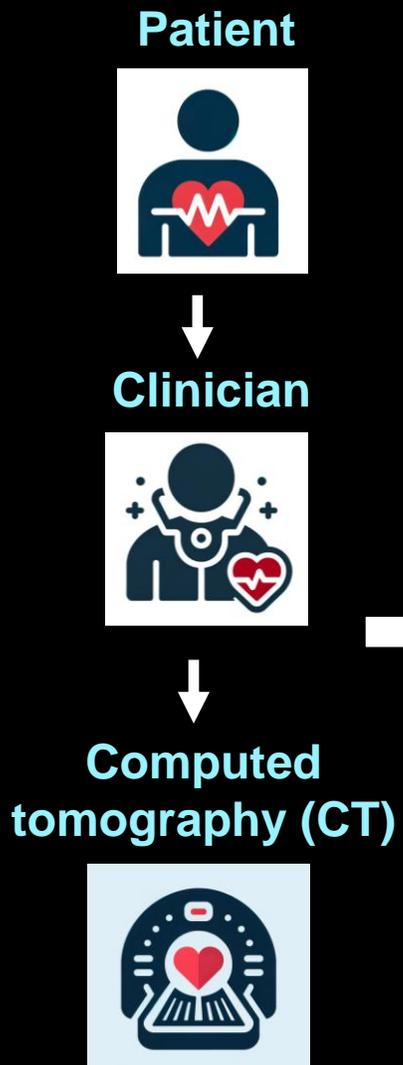


Del TAC a la sala de Cardiología Intervencionista: Que lesiones tratar y como



Trans Aortic Valve Implantation **TAVI**





CalciGrapher
workstation



Diagnosis



TAVR planning



Post-TAVR monitoring

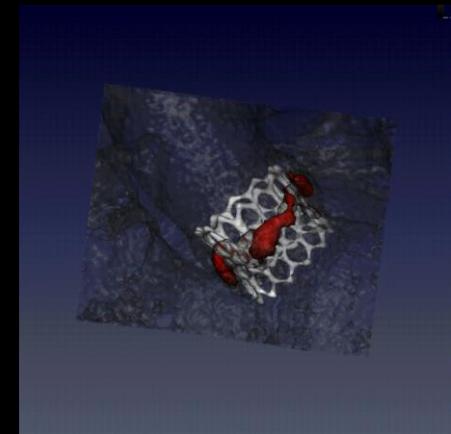
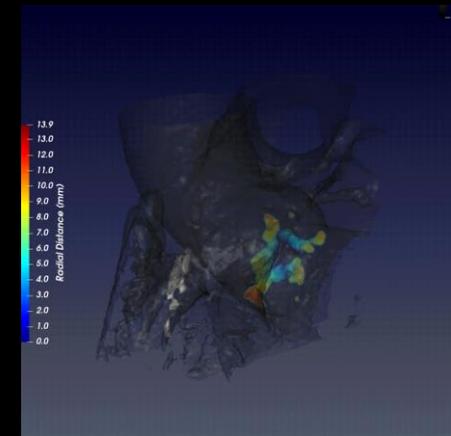
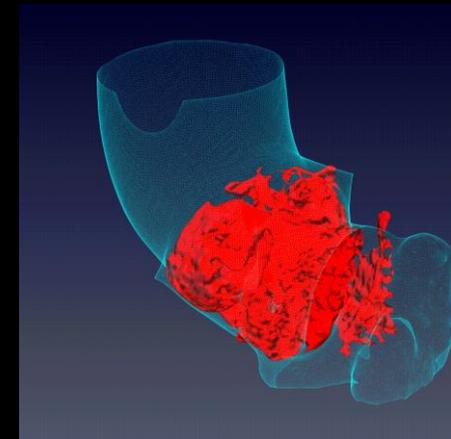


Accurate (quantitative)
CT assessment of
calcification

Patient specific
automatic regional
calcific assessment

Automated peri-
procedural
outcome/event
prediction

Post-procedural
monitoring



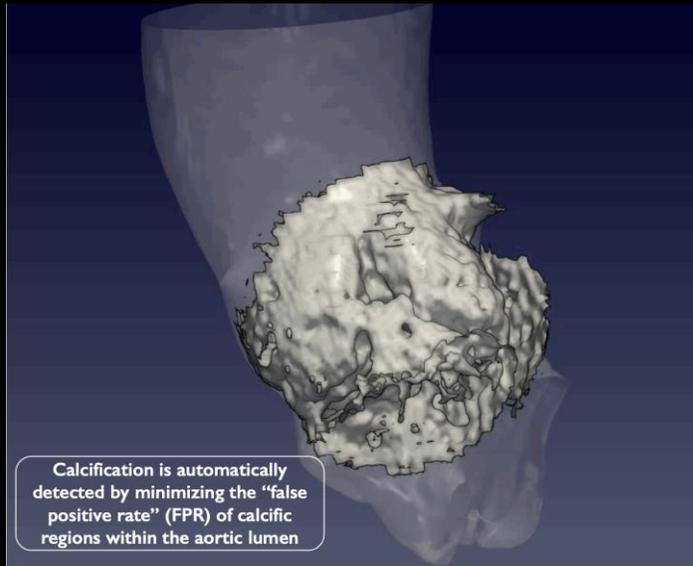
AS diagnosis

AS reclassification
& AS staging

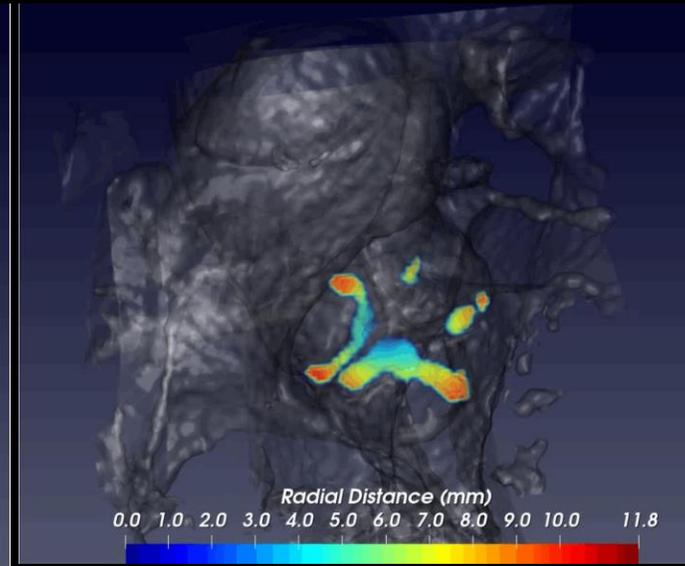
TAVR planning
& optimization



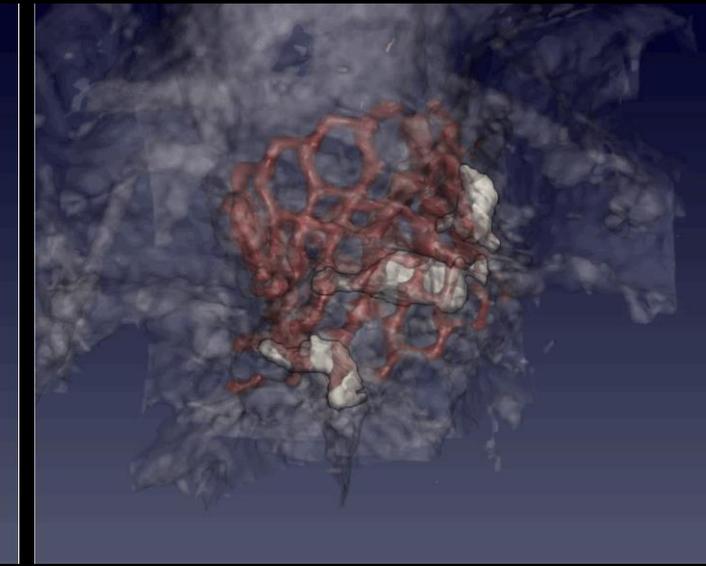
CalciGrapher



Excellent agreement with standard CT and ECHO determinants of AS severity



Ability to quantify regional calcific progression across sex and severity



Ability to predict common periprocedural outcomes/events of TAVR

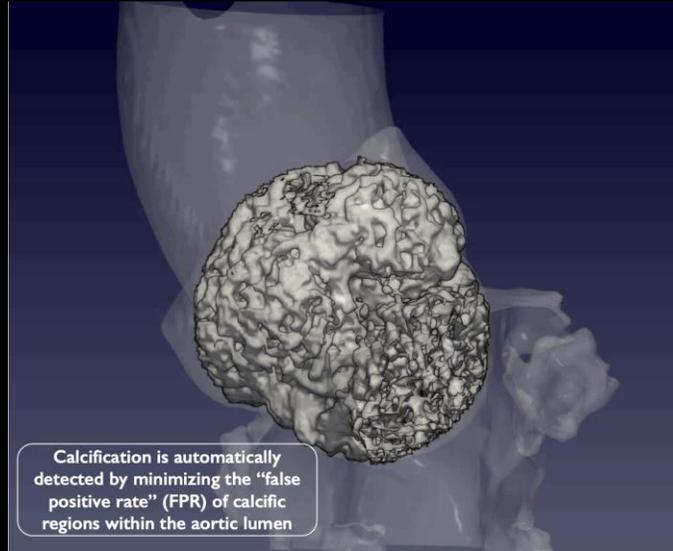
BAS diagnosis

BAS reclassification
& BAS staging

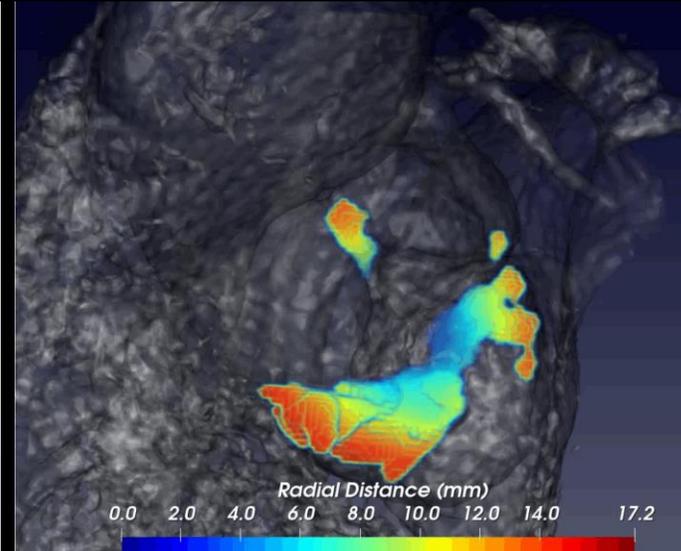
TAVR planning
& optimization



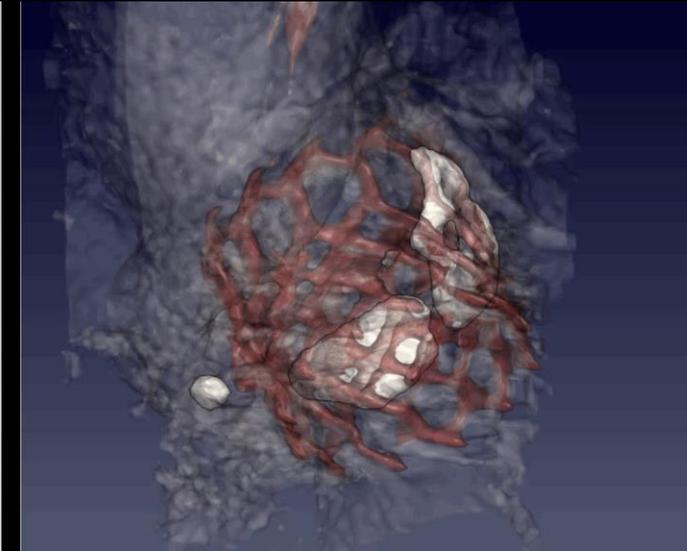
CalciGrapher



Excellent agreement with standard CT and ECHO determinants of the valve stenosis severity

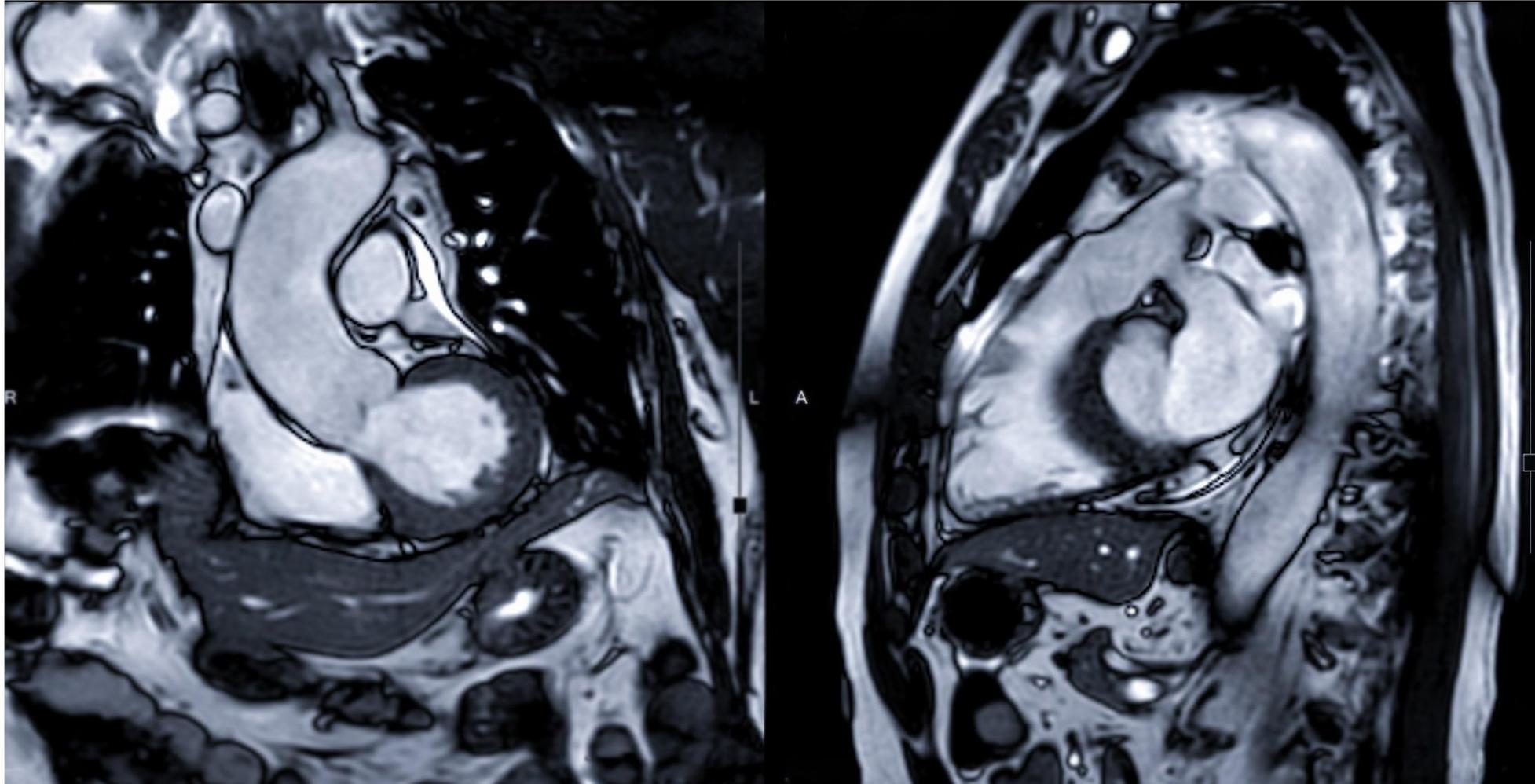


Ability to quantify regional calcific progression across sex and severity

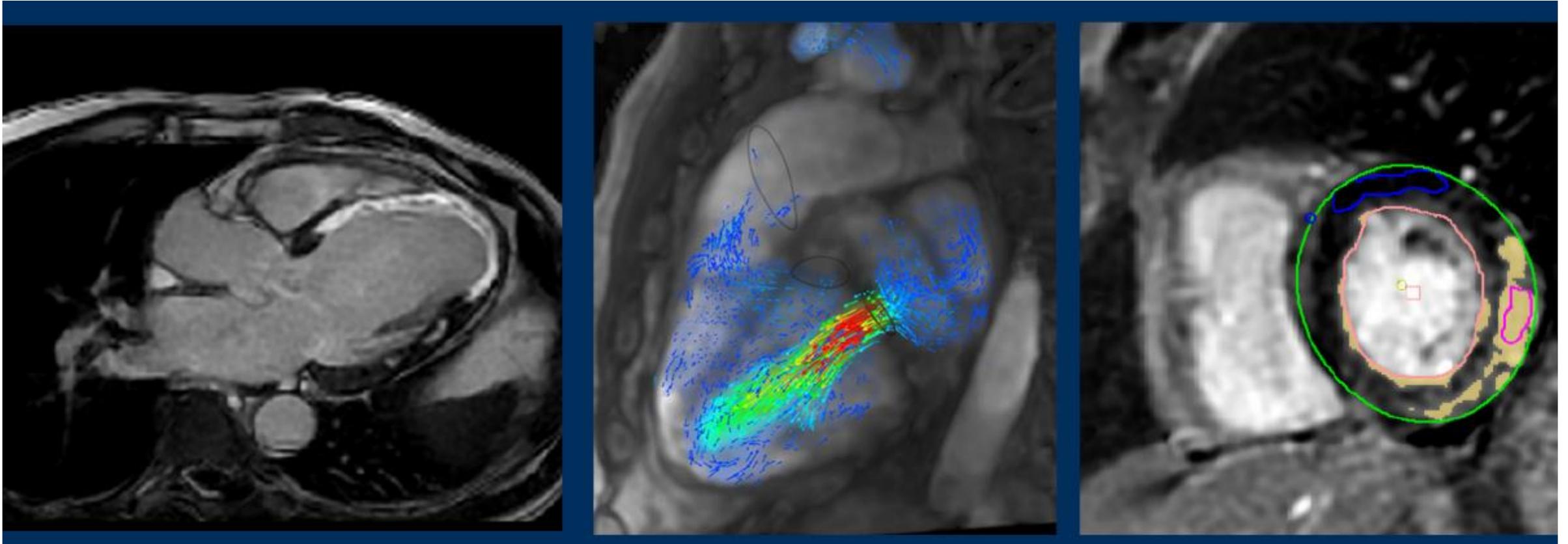


Ability to predict common periprocedural outcomes/events of TAVR

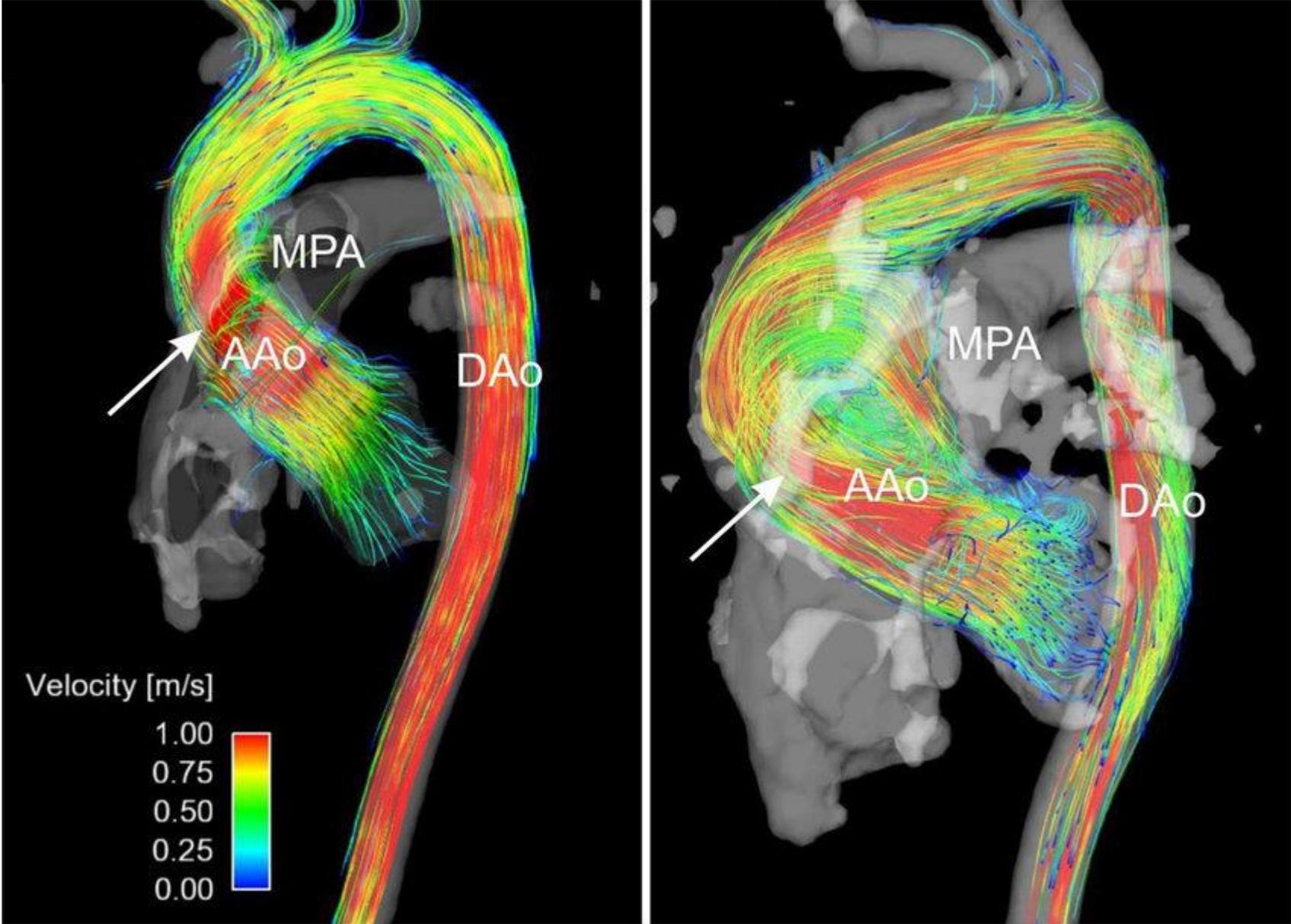
RMN cardiaca



RMN cardíaca: análisis tisular, fisiología



RMN 4D flow



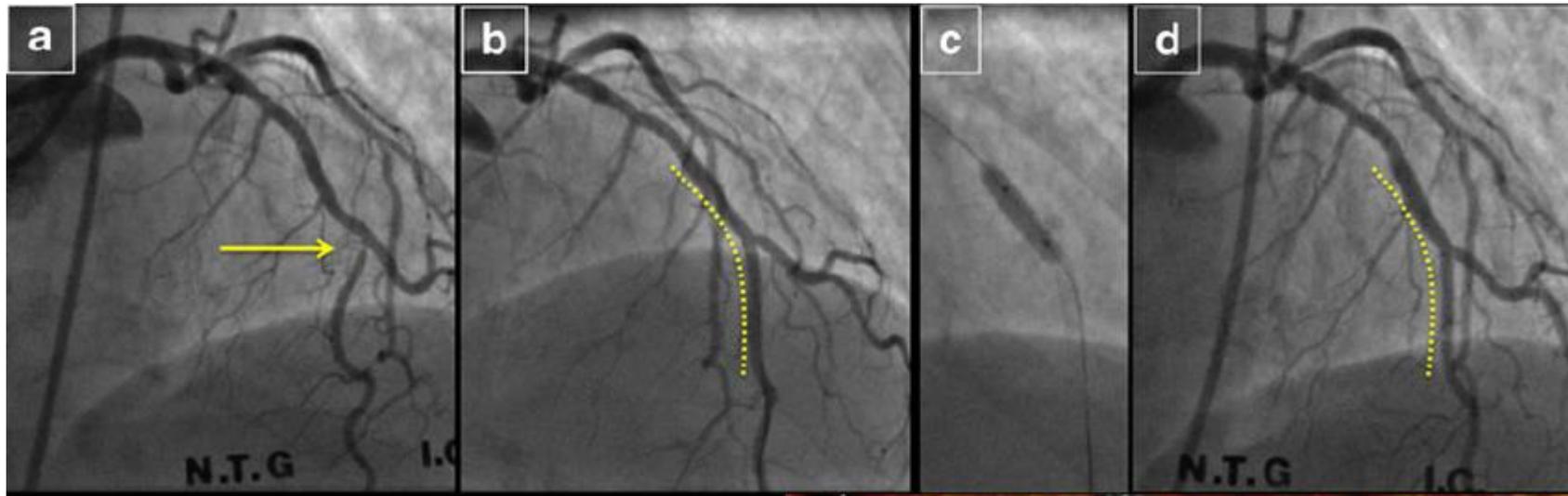
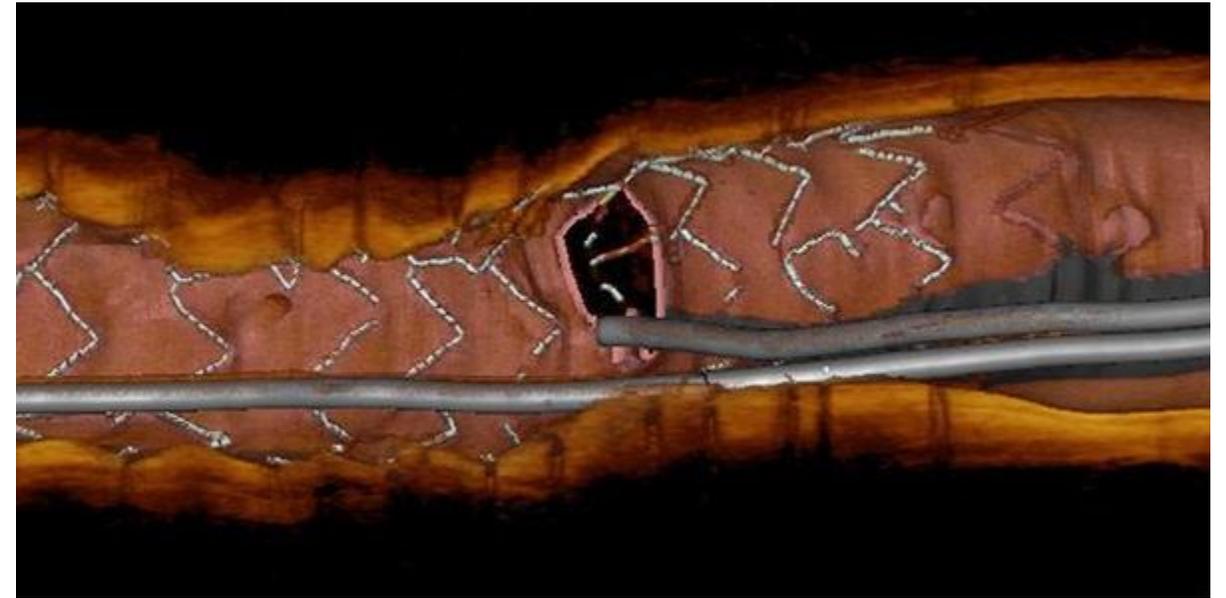
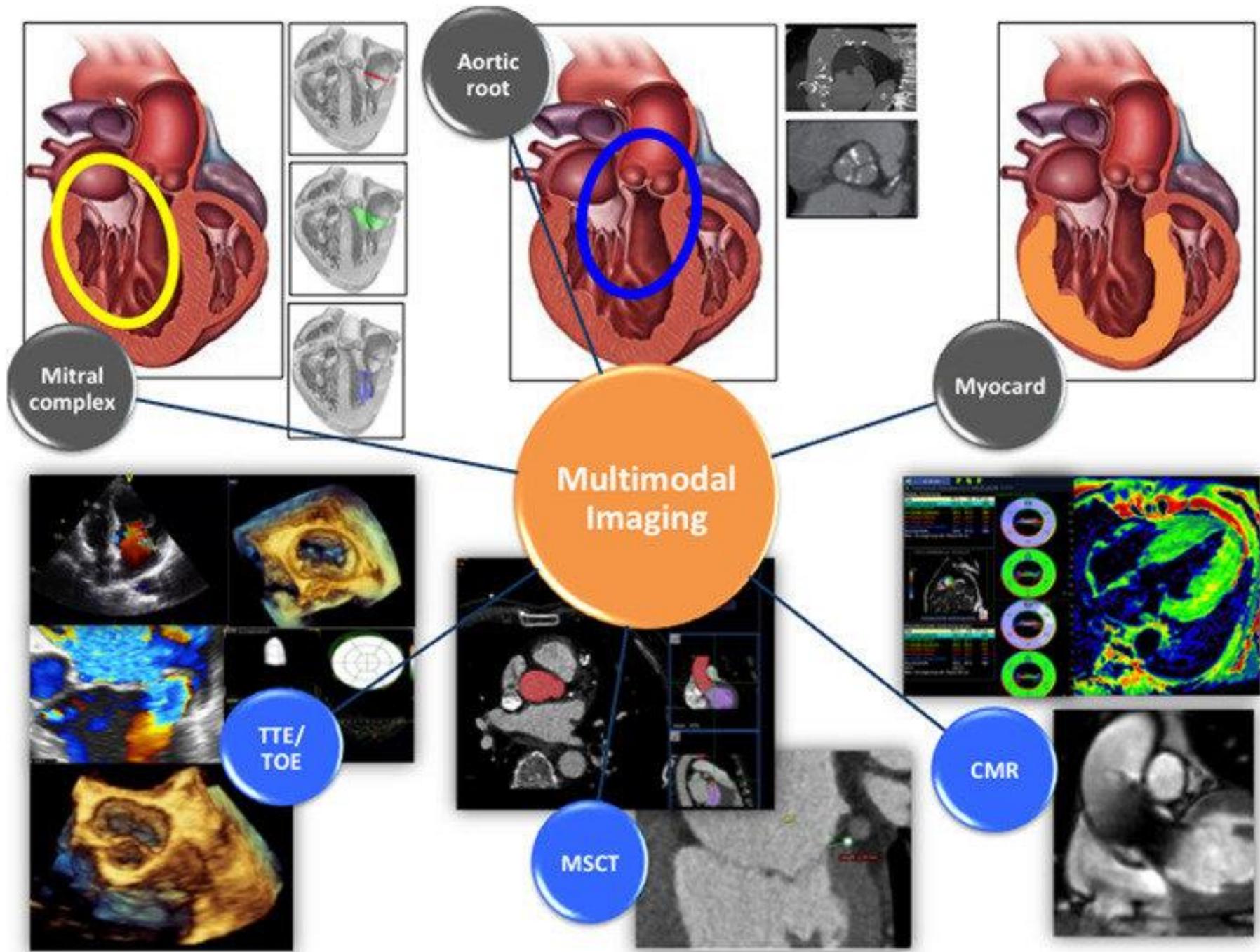
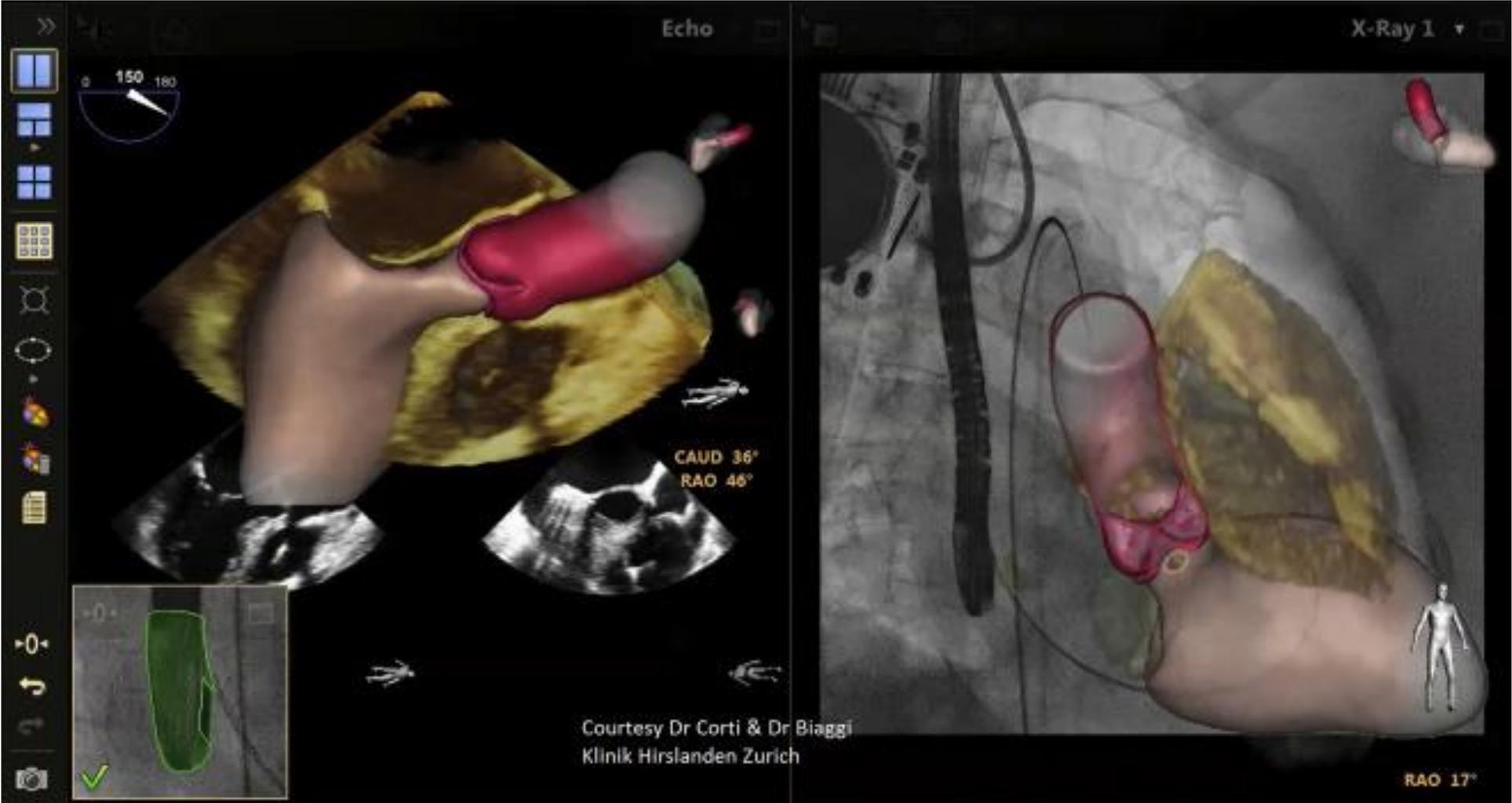


Imagen intravascular OCT 3D

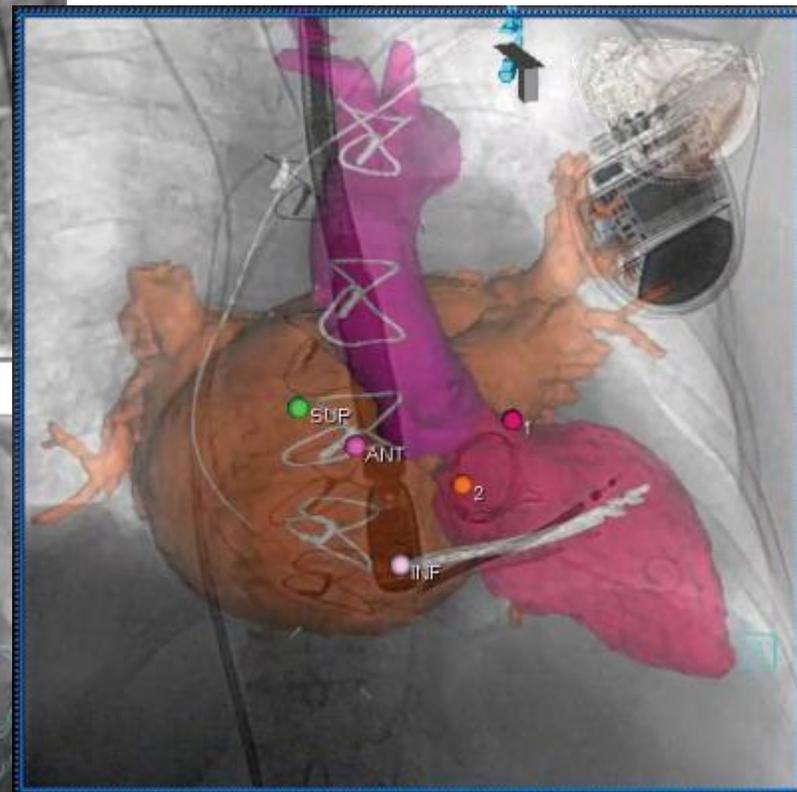
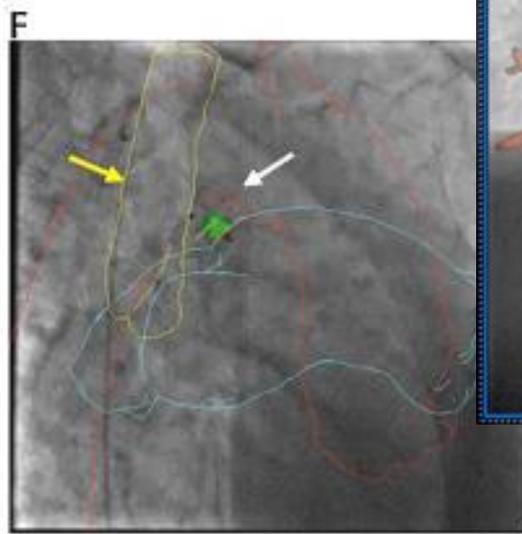
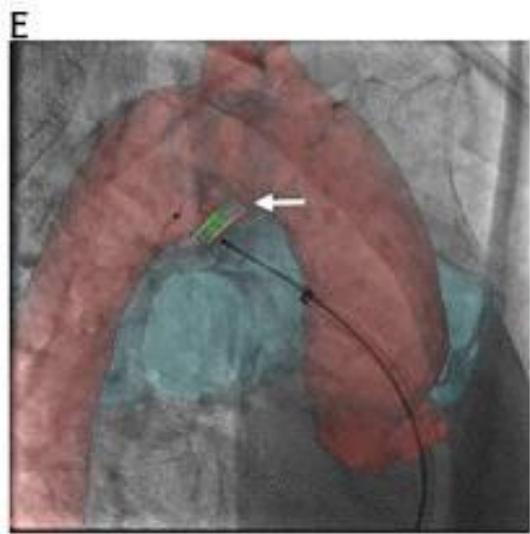
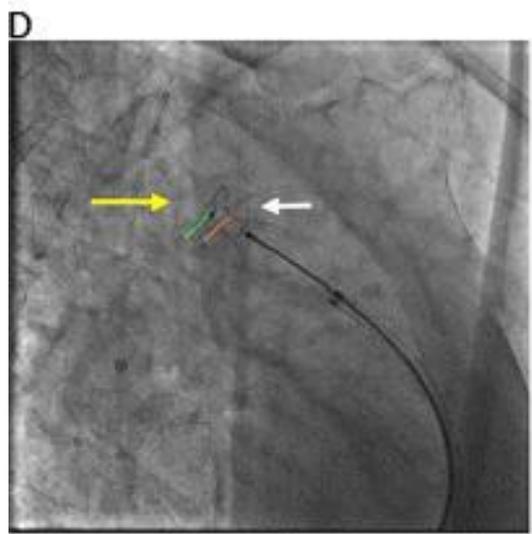
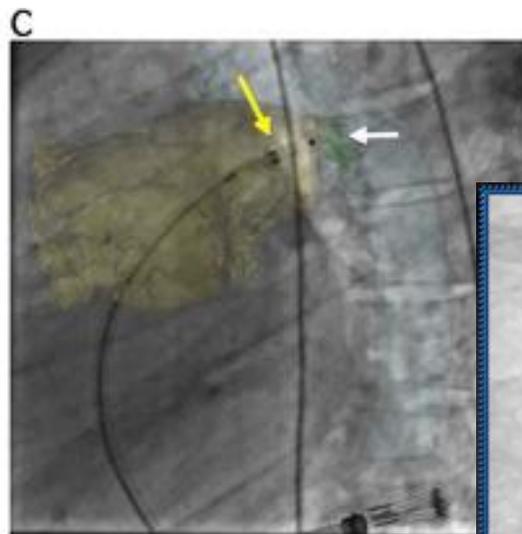
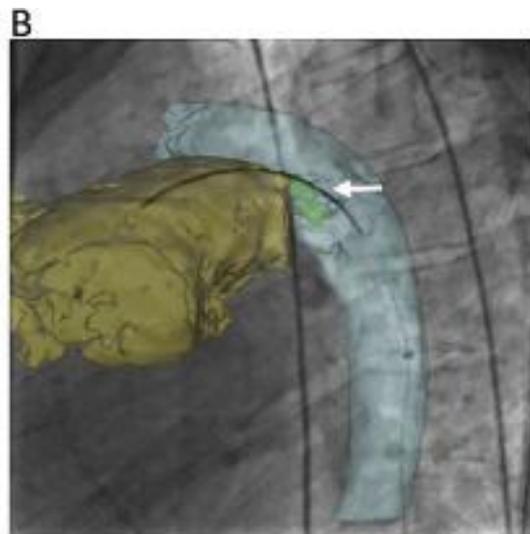
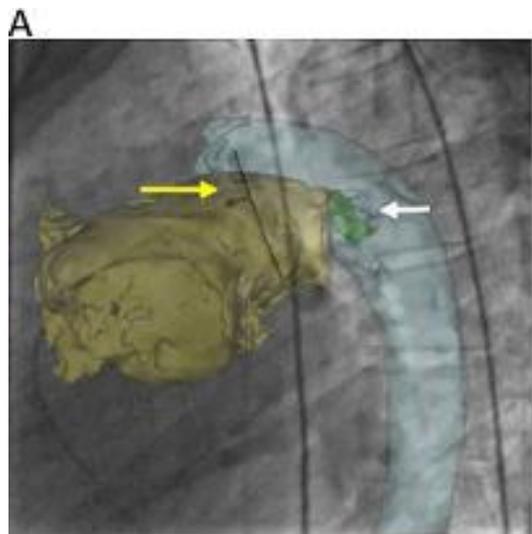




Fusión Ecocardiografía + Angiografía

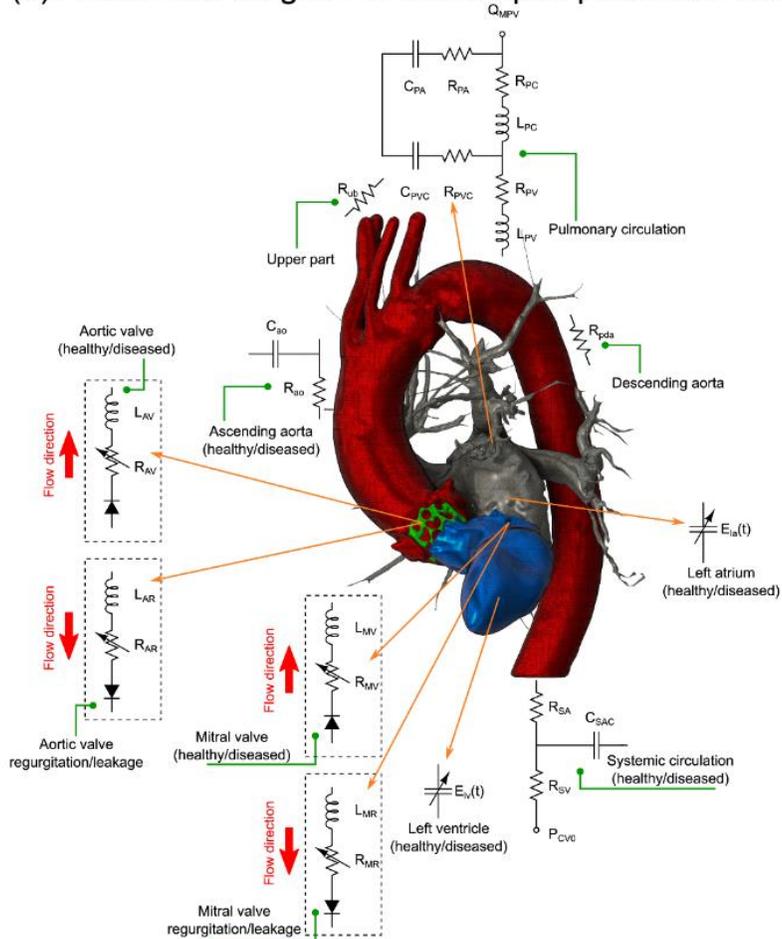


Fusión TAC + Angiografía

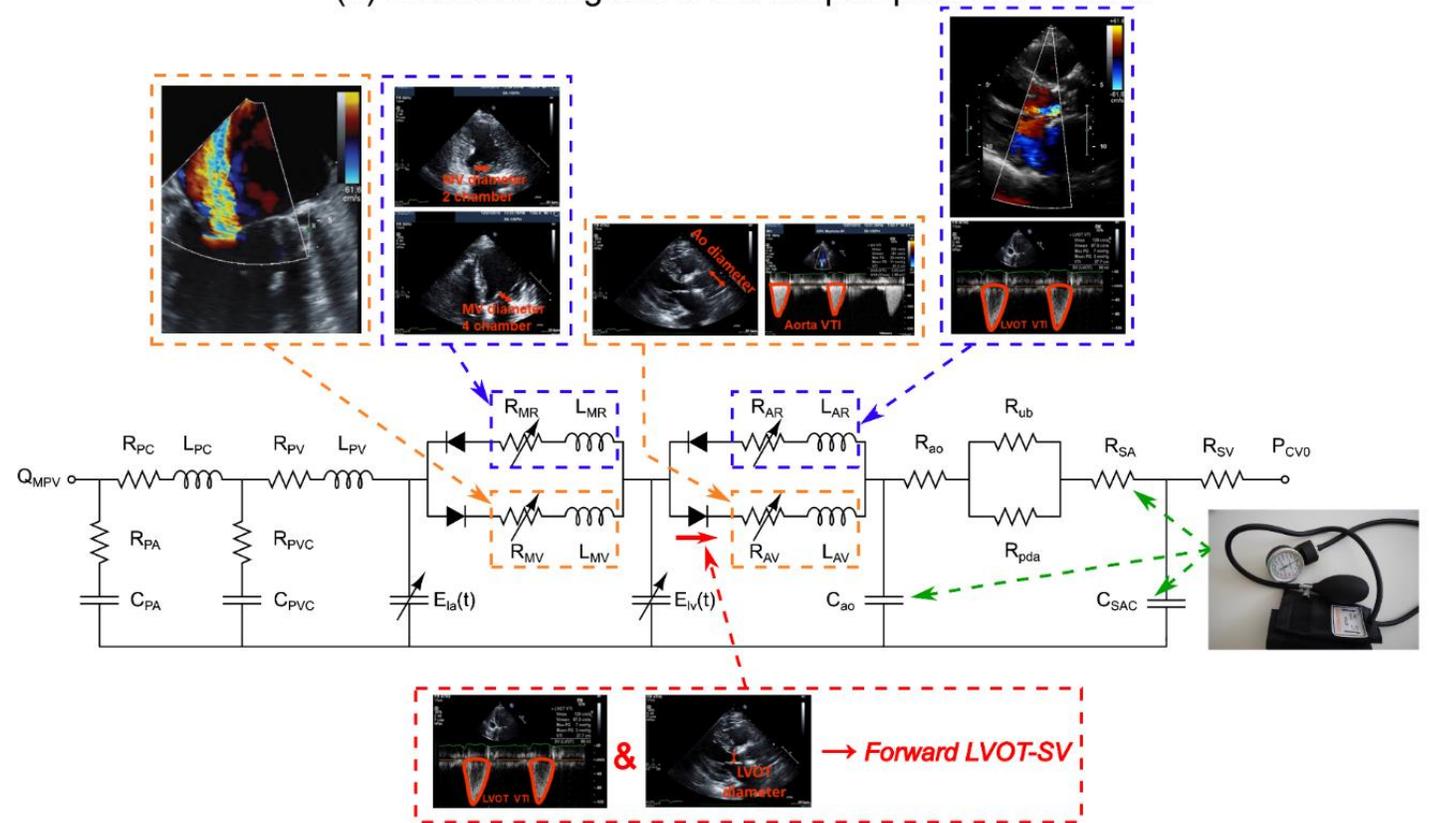


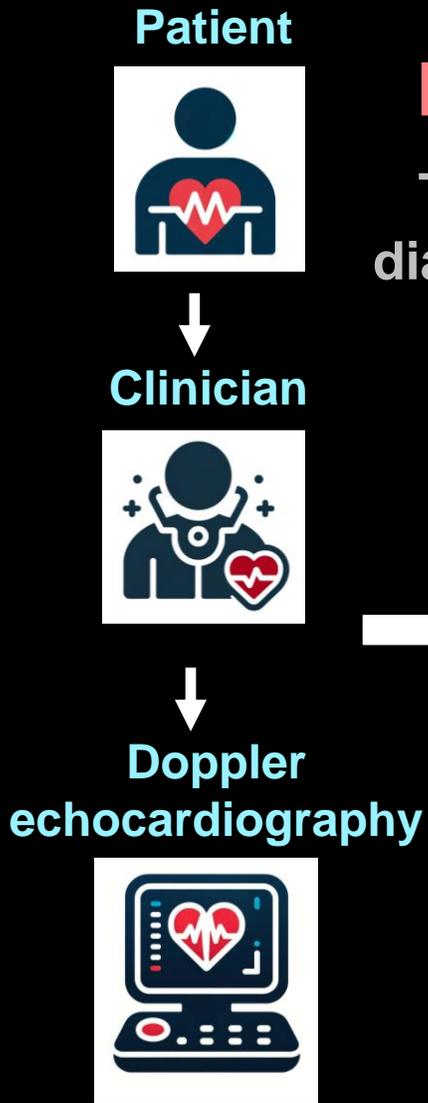
De la imagen a la fisiología

(a) Anatomical diagram of the lumped parameter model



(b) Electrical diagram of the lumped parameter model





DiagnoCardio
 The Doppler-based diagnostic, monitoring and predictive framework



CD Diagnosis



Intervention prediction



Post-intervention monitoring

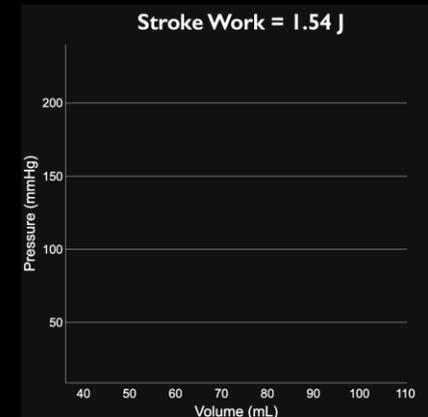
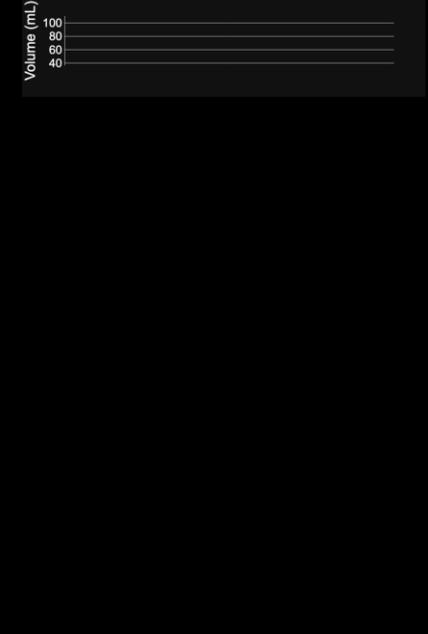
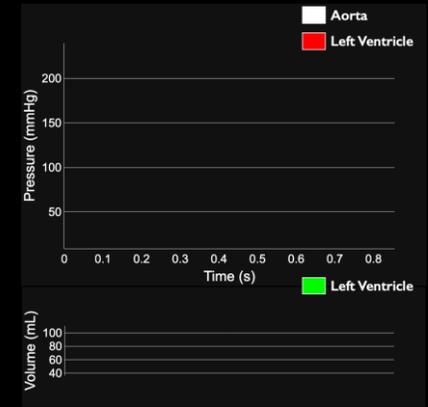


Quantifying physiological flow and pressures through the heart and circulatory system

Performing P-V loop analysis

Quantifying heart-function metrics, e.g., LV workload, LV pressure, LV end-diastolic pressure, contractility

Providing the breakdown of effects of each disease constituents on the cardiac function



RETOS

Elevado coste, la **necesidad de equipos multidisciplinares** (recelos gremiales, acusación de intrusismo, competitividad y percepción de amenaza).

Mantenimiento de hardware y software, la **exposición a la radiación** en algunas modalidades y la **interpretación** de datos de imagen complejos.

Integración de los hallazgos de imagen en los procesos de toma de decisiones clínicas.

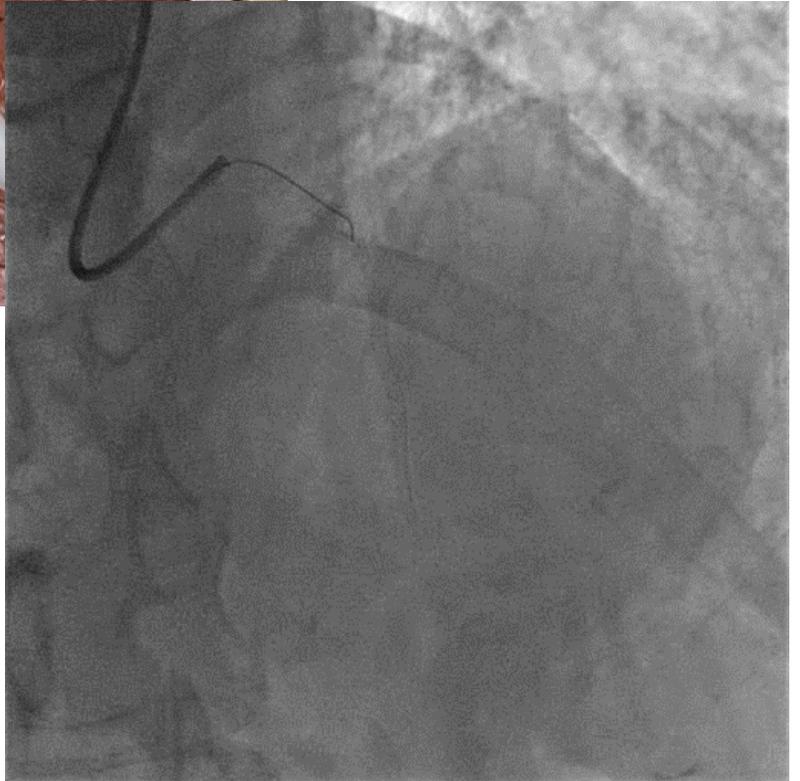
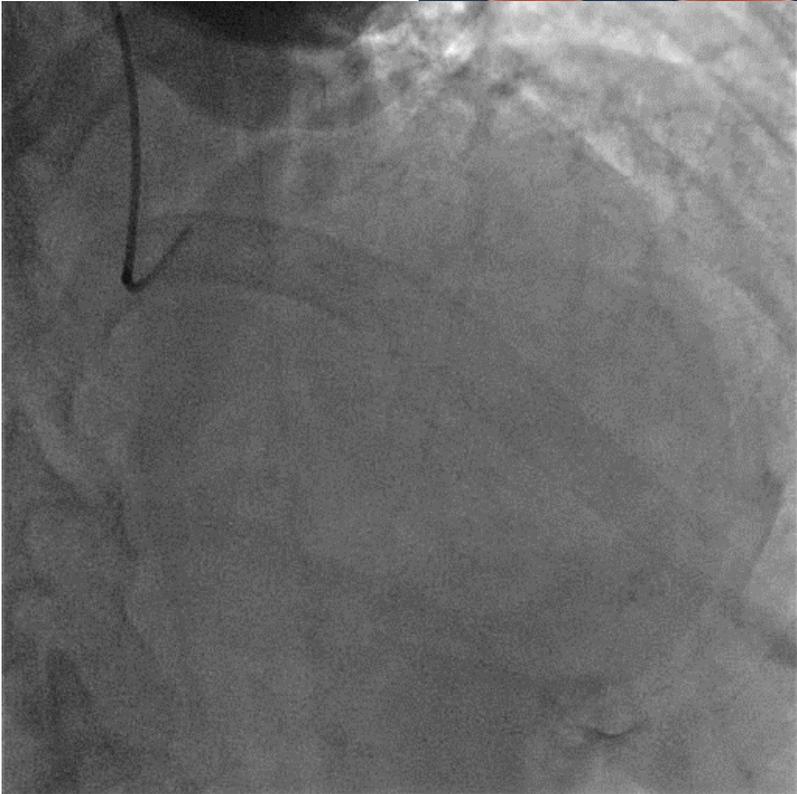
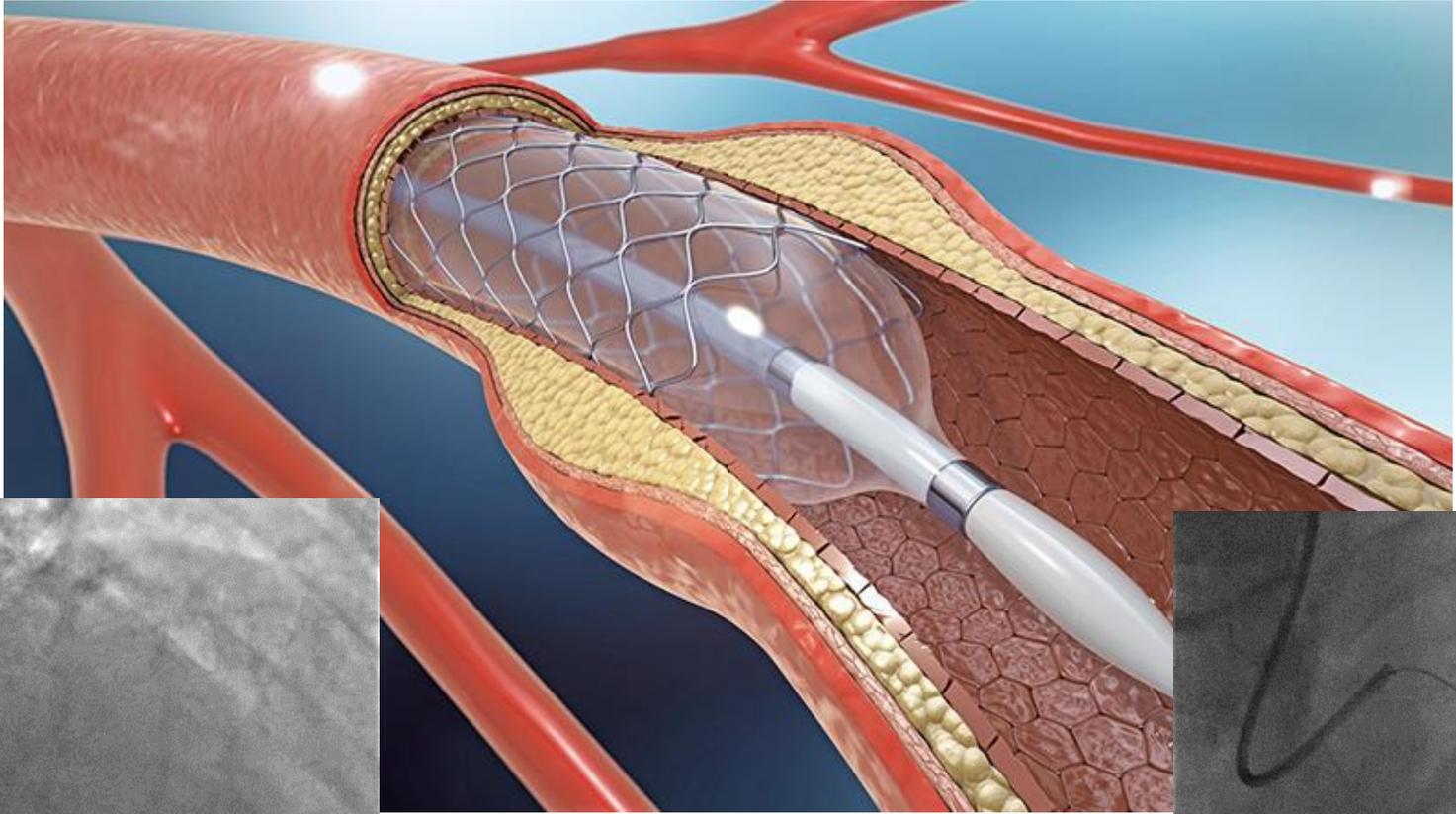
Radiólogos, Cardiólogos, y demas



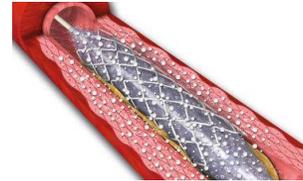
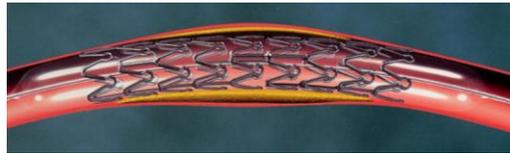
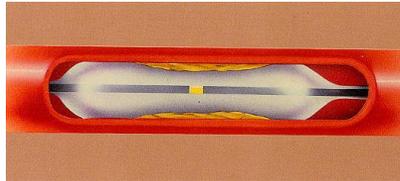
**Cultura del trabajo multidisciplinar
Superar el “tribalismo” de los Servicios Clínicos**

Procedimientos mínimamente invasivos: *La revolución de las intervenciones por cateter*





Evolución en dispositivos para Intervencionismo Coronario

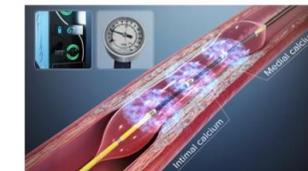
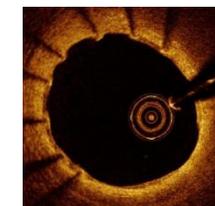
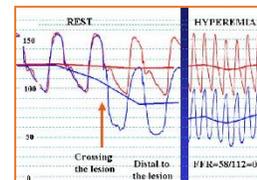
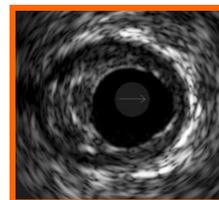
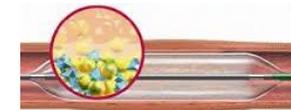
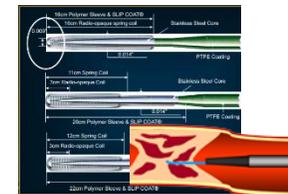
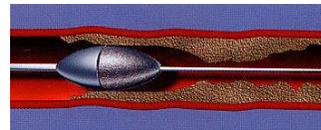


1977

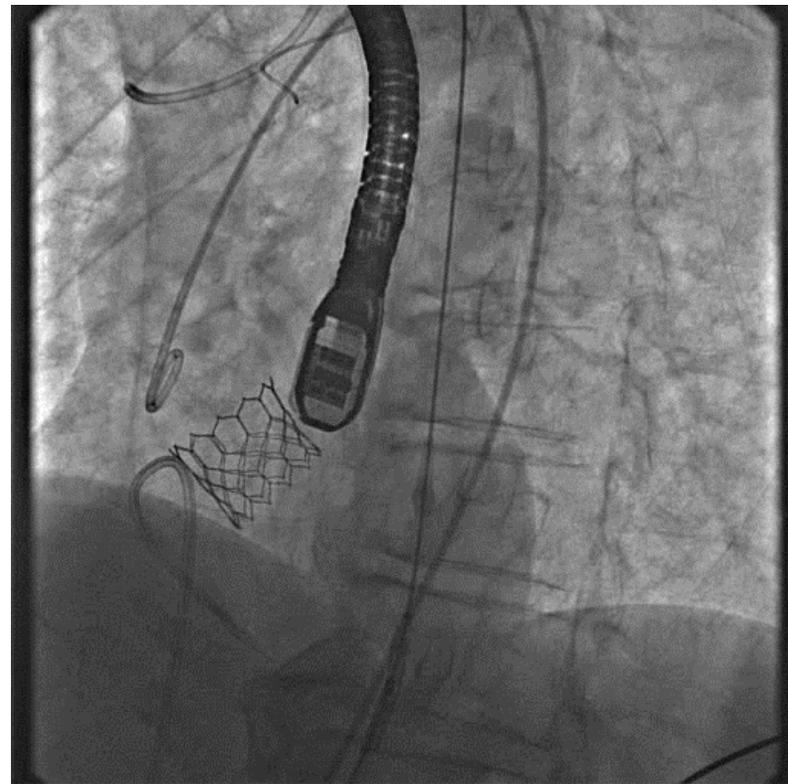
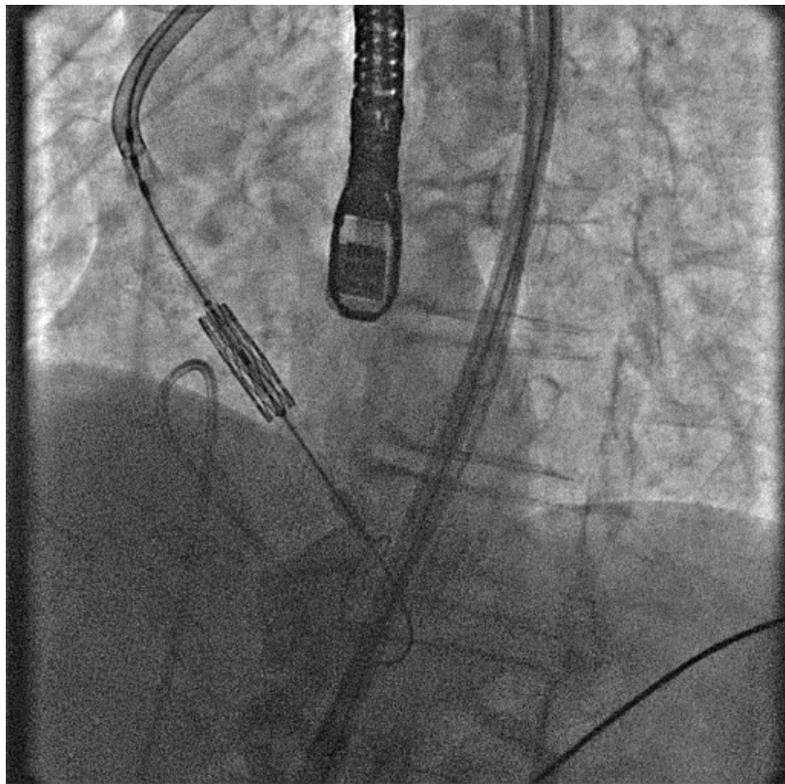
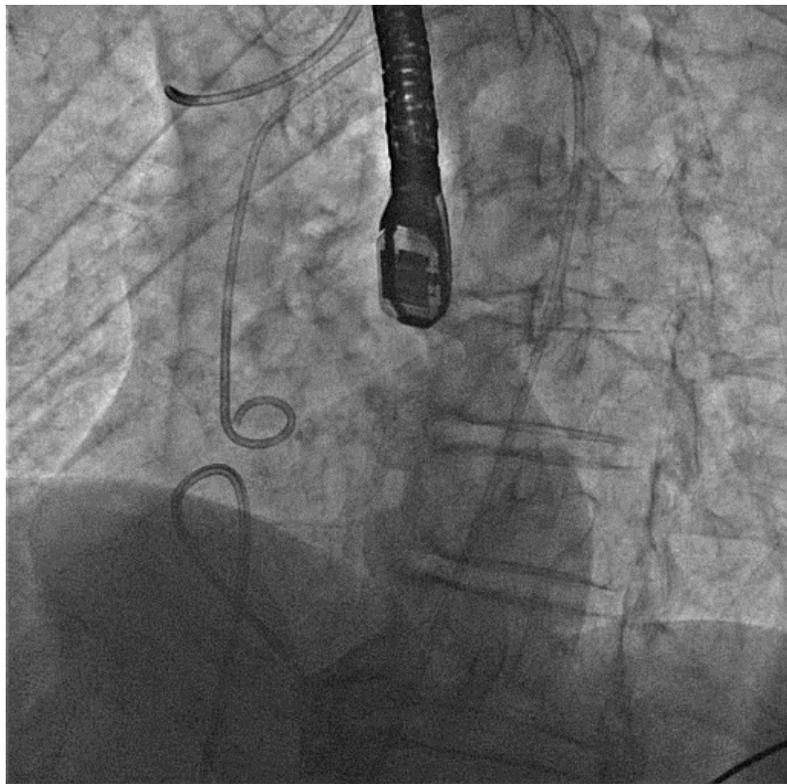
1990

2002

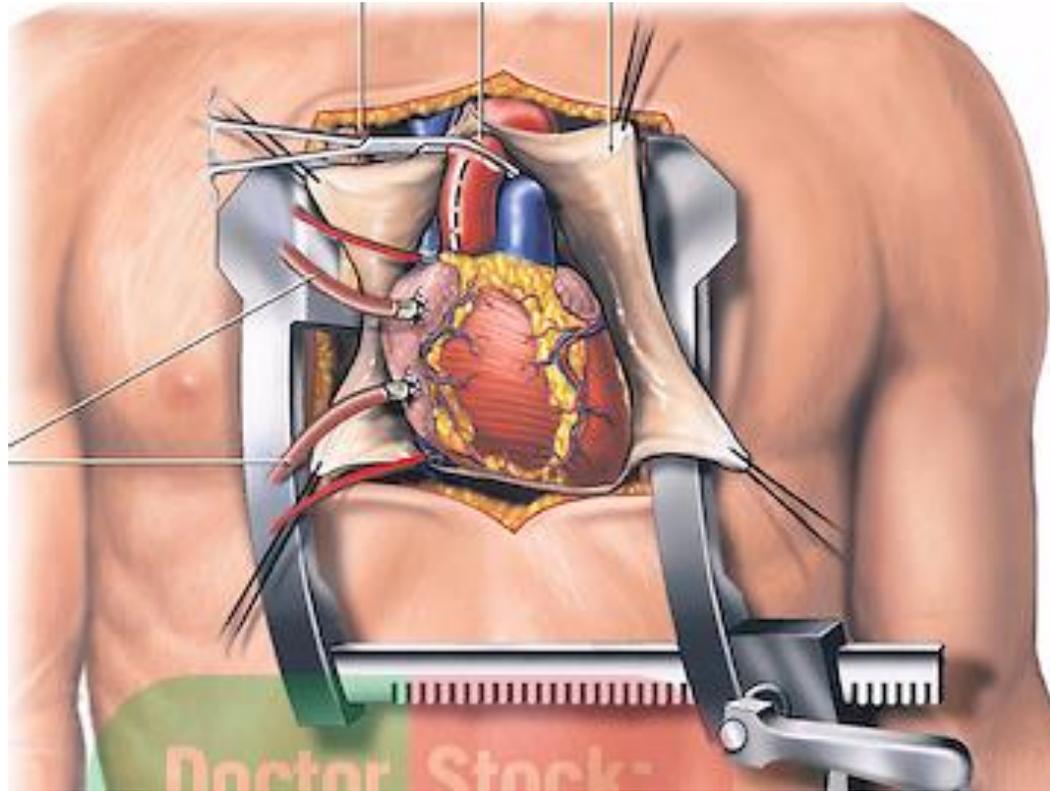
2024



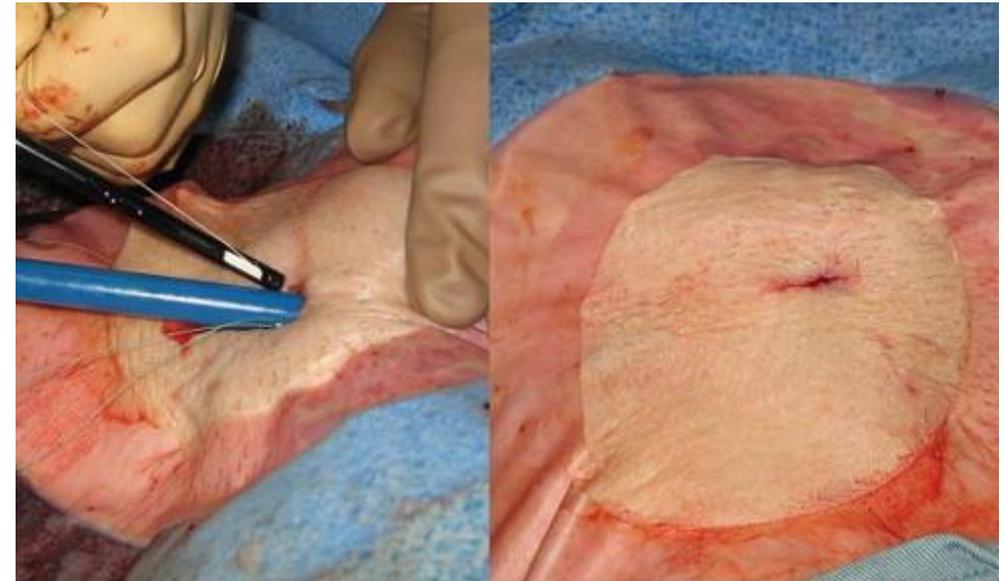
Abciximab AAS+Ticlopid./Clop. Bivalirudina, Prasugrel /Ticagrelor, Cangrelor, ...

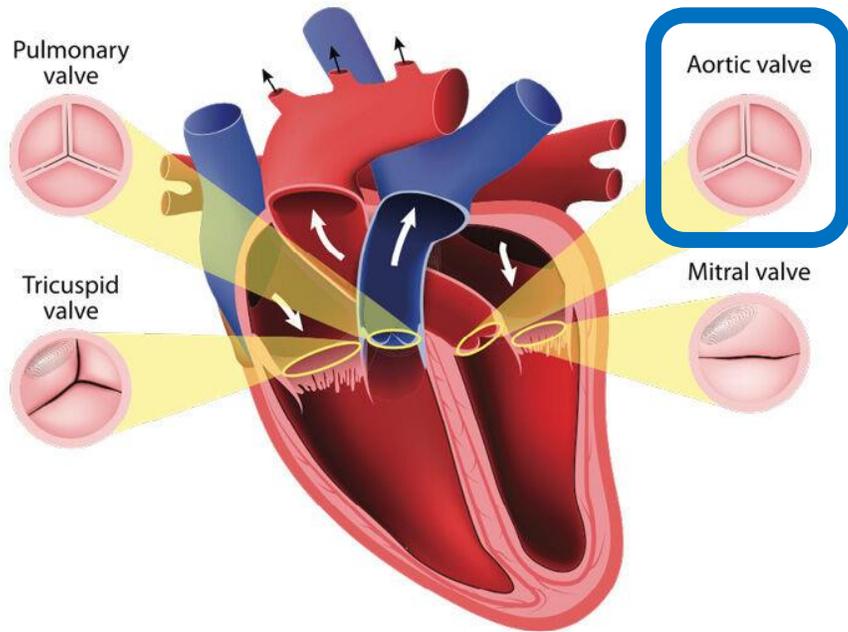


Cirurgia

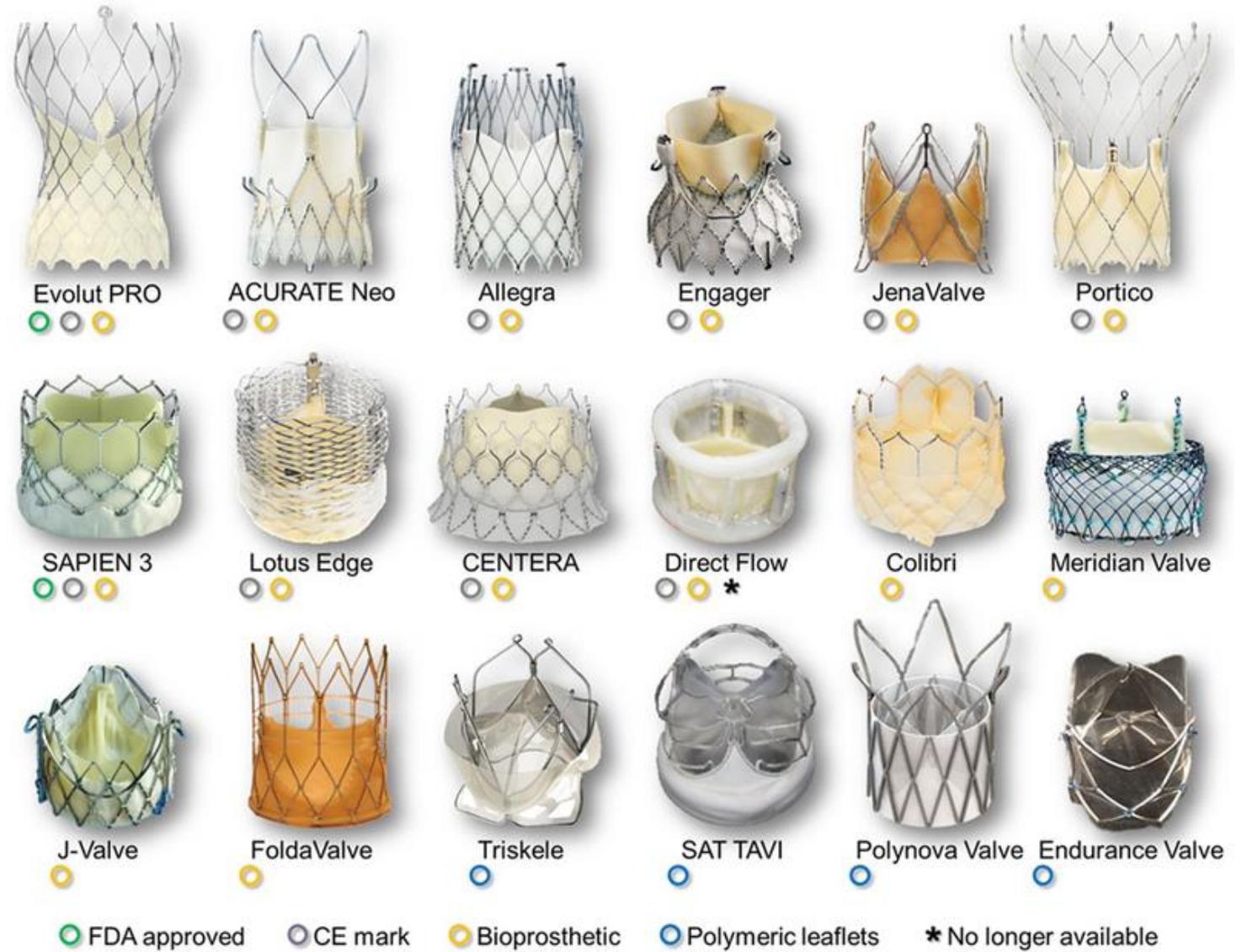


TAVI





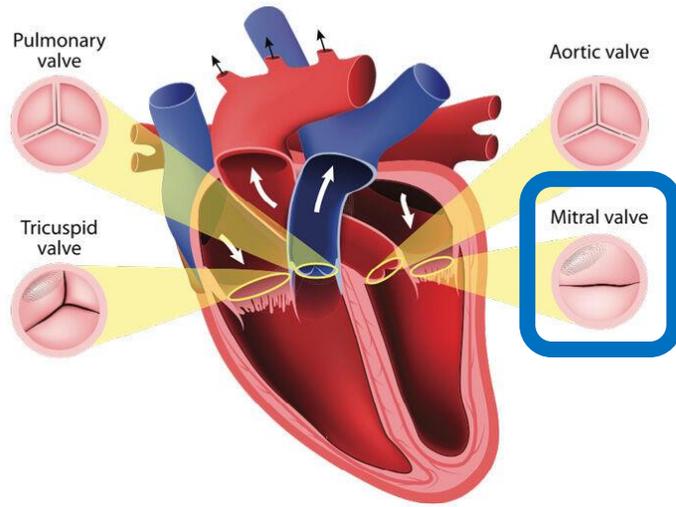
Aortica



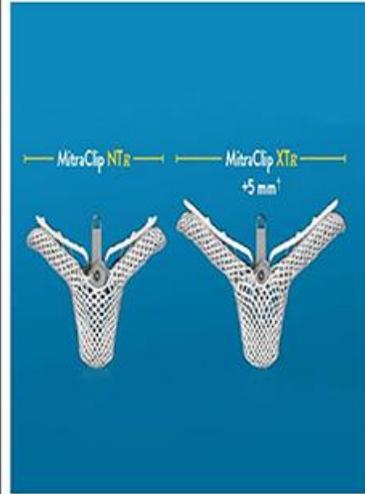
Feature | Heart Valve Technology | November 17, 2020

TAVR Is Now Dominant Form of Aortic Valve Replacement in the United States

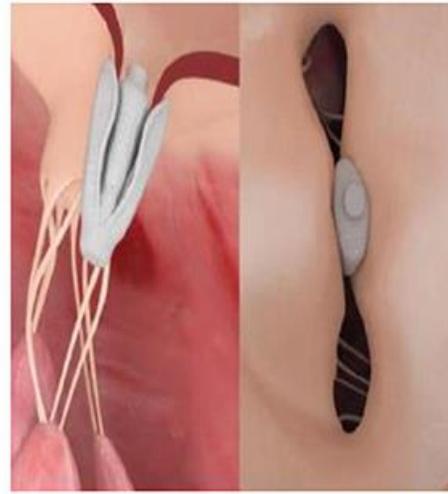
Mitral



Edge-to-edge repair

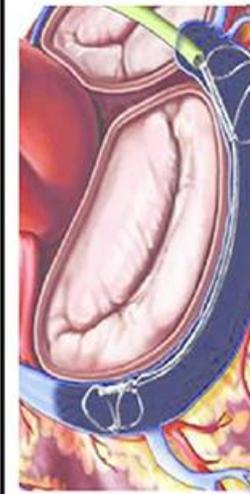


Newer generation MitraClip

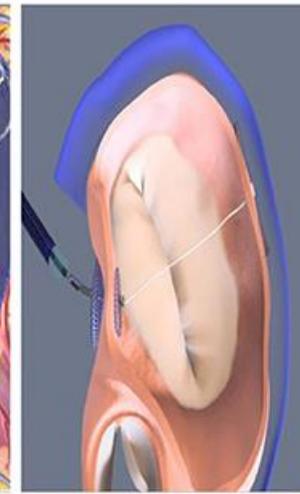


Pascal

Indirect annuloplasty



Carillon

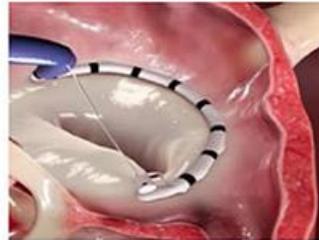


MVRx ARTO

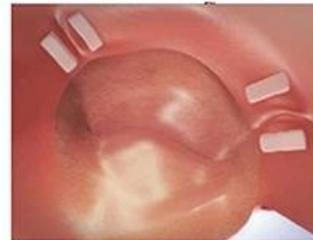


Mitral Loop Cerclage

Direct annuloplasty



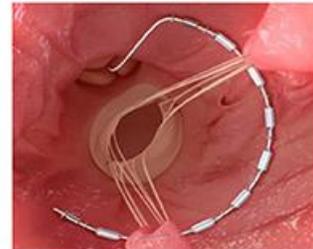
Cardioband



Mitralign



Millipede



Accucinch

Chordal replacement



NeoChord

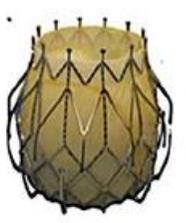
Transcatheter replacement



Sapien 3



Intrepid



CardiaQ

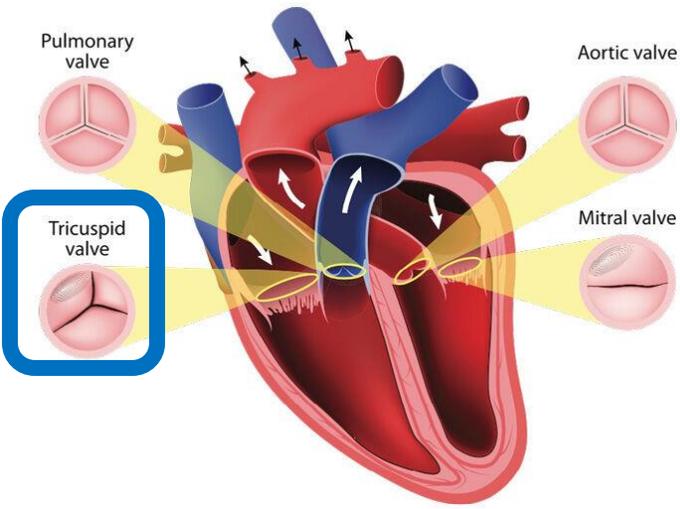


Tiara



Caisson

Tricuspid



Direct suture annuloplasty



Direct ring annuloplasty



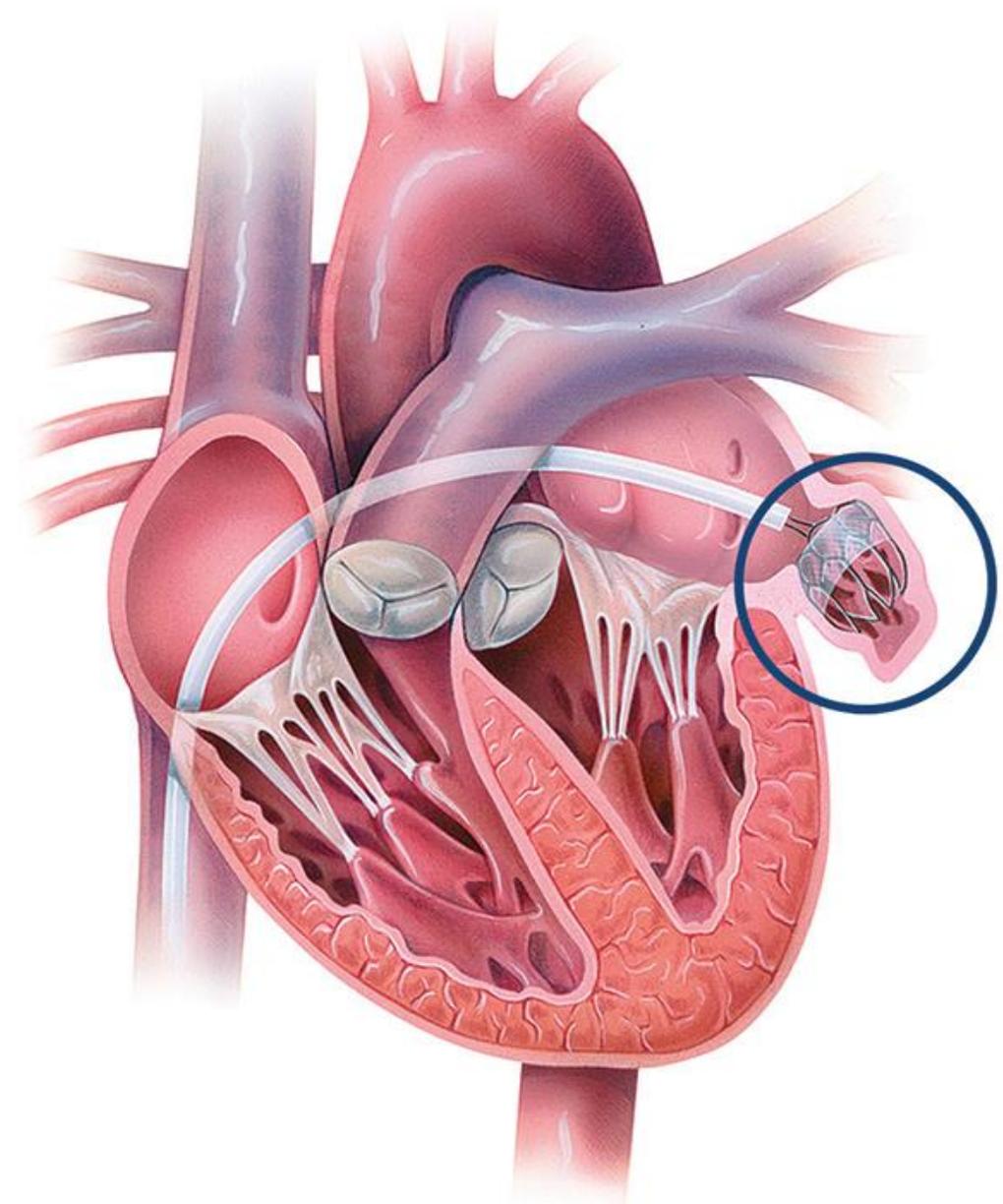
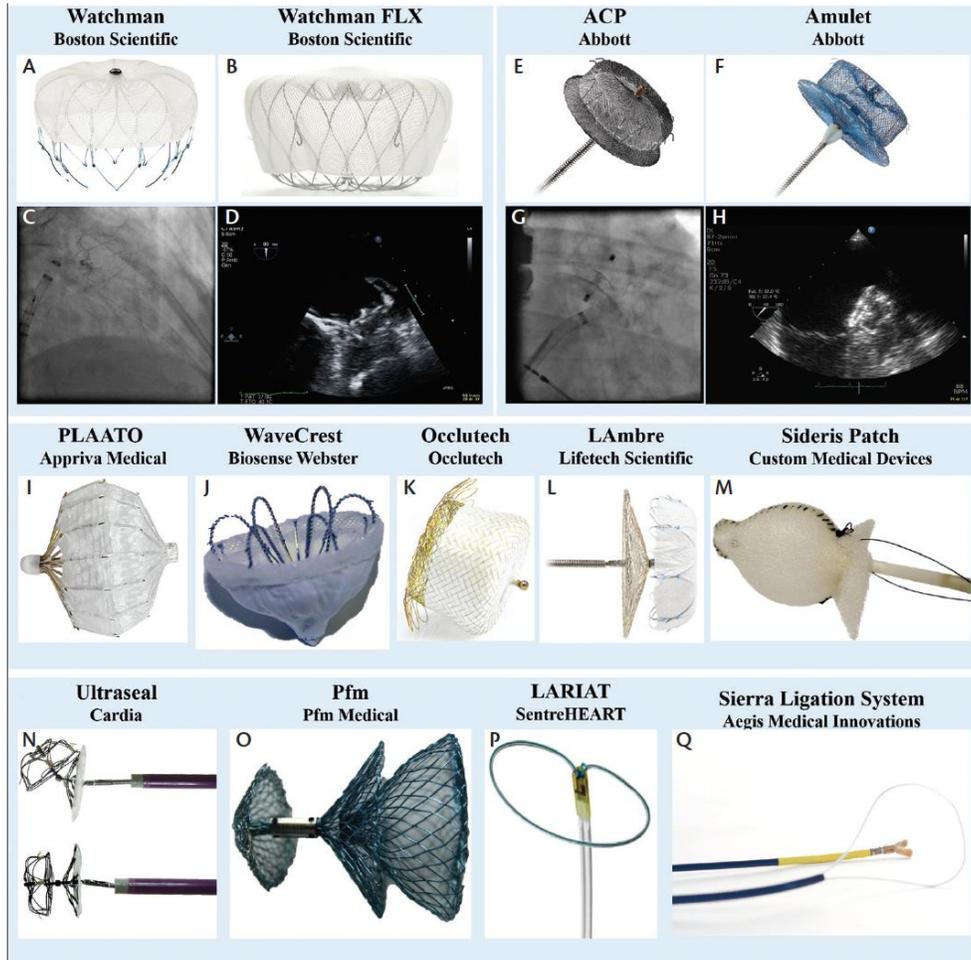
Coaptation enhancement



Valve replacement

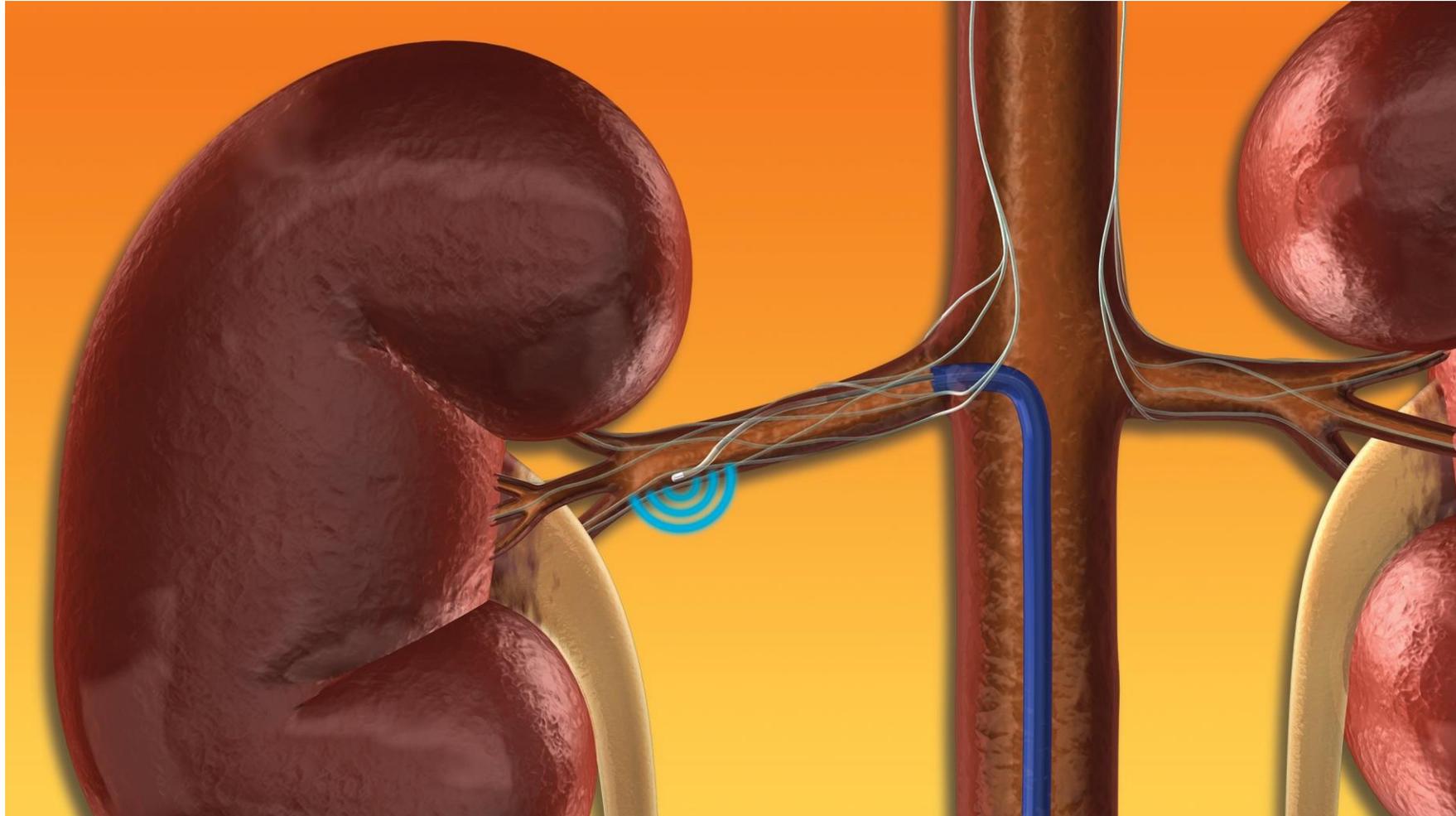


Cierre de orejuela

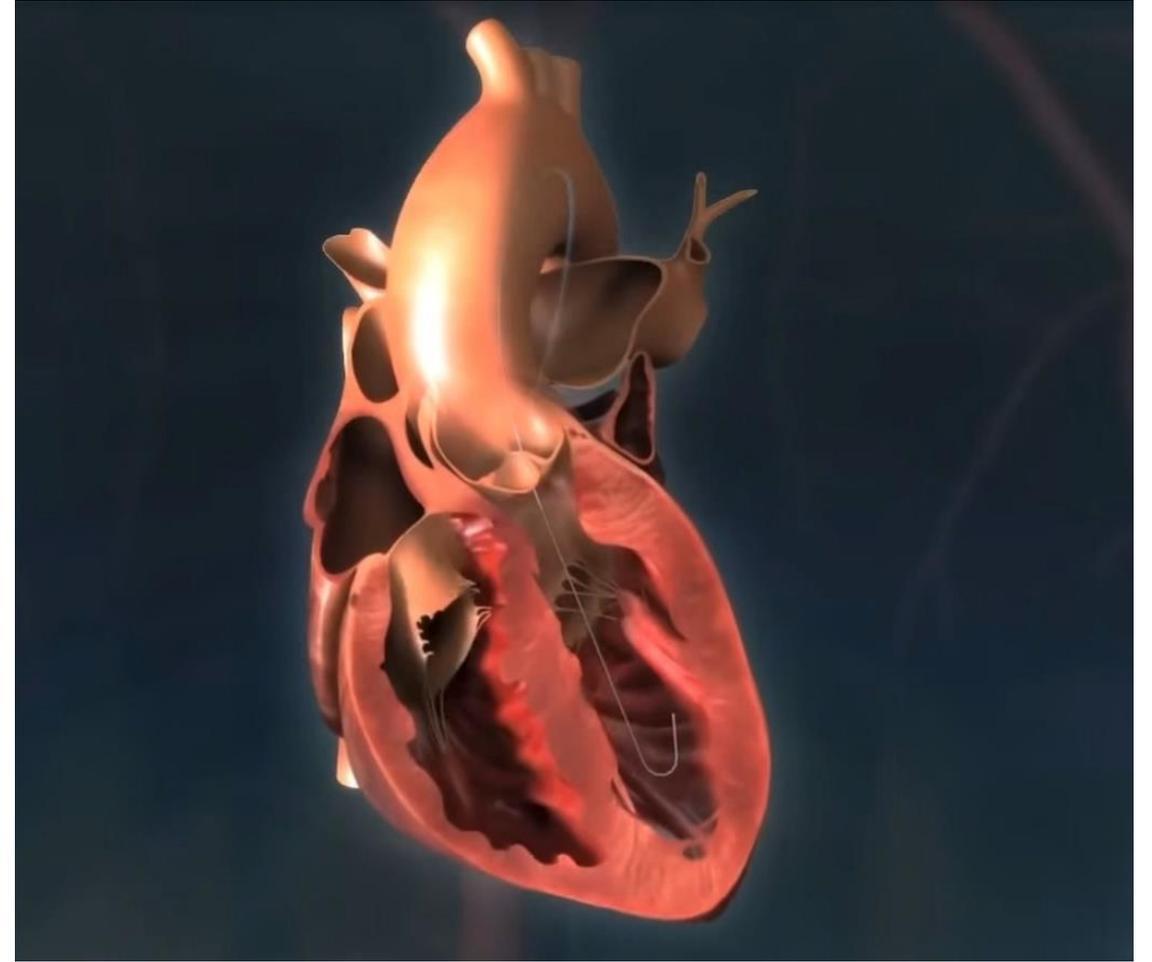
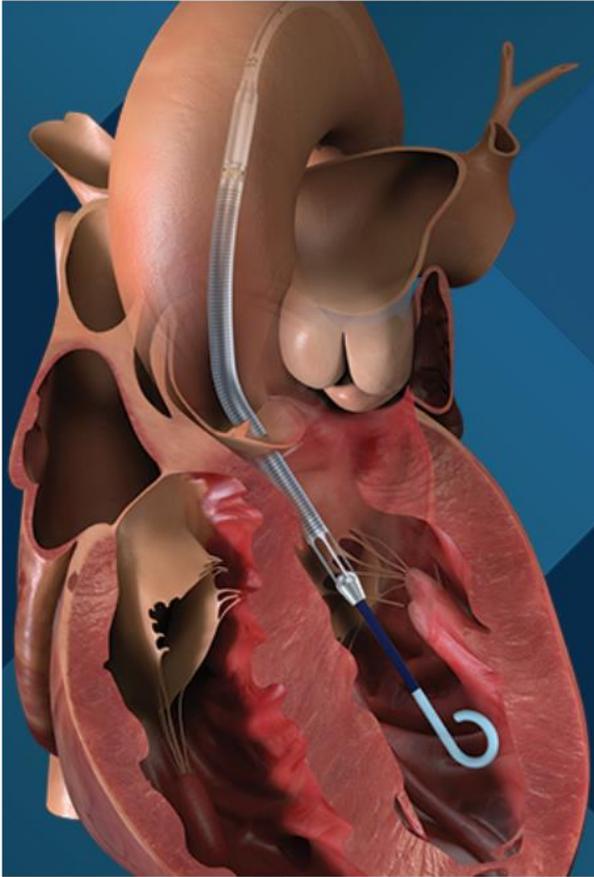


Denervacion renal

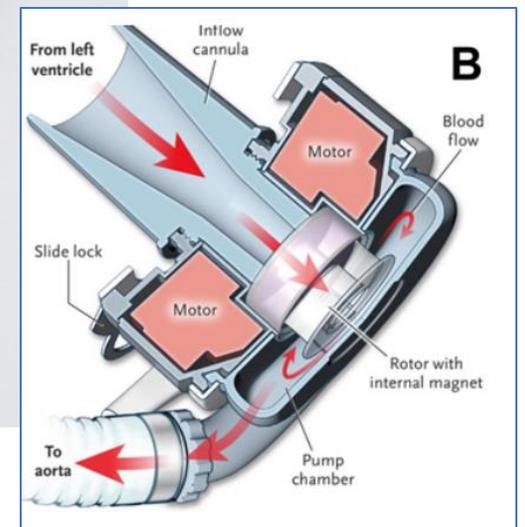
Tratamiento de la HTA resistente

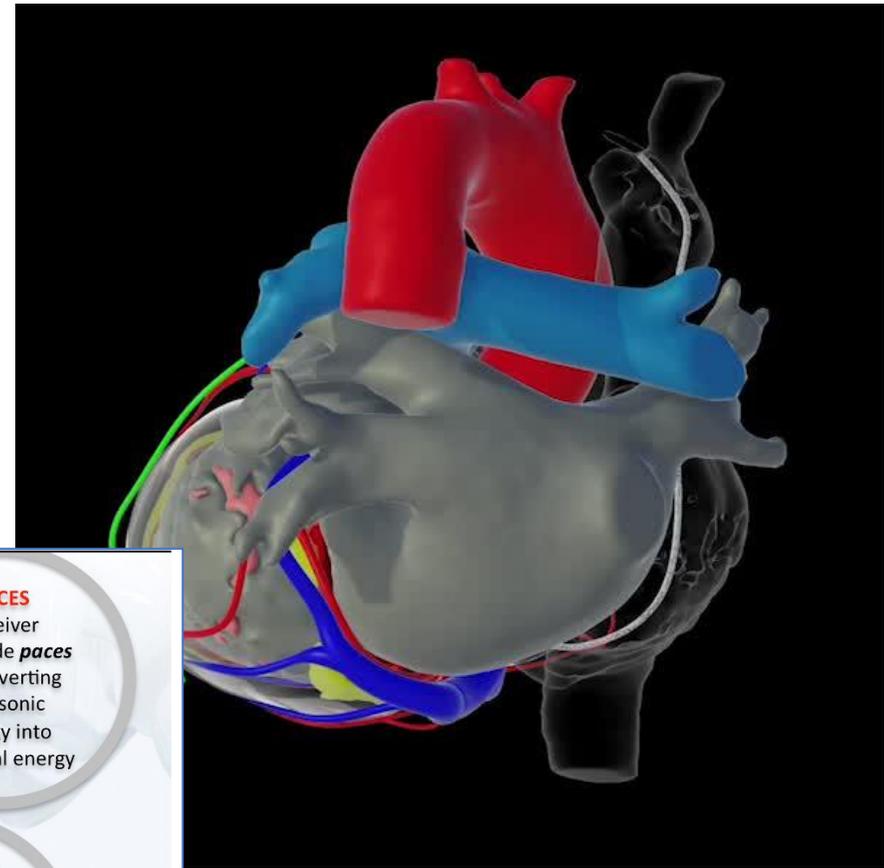
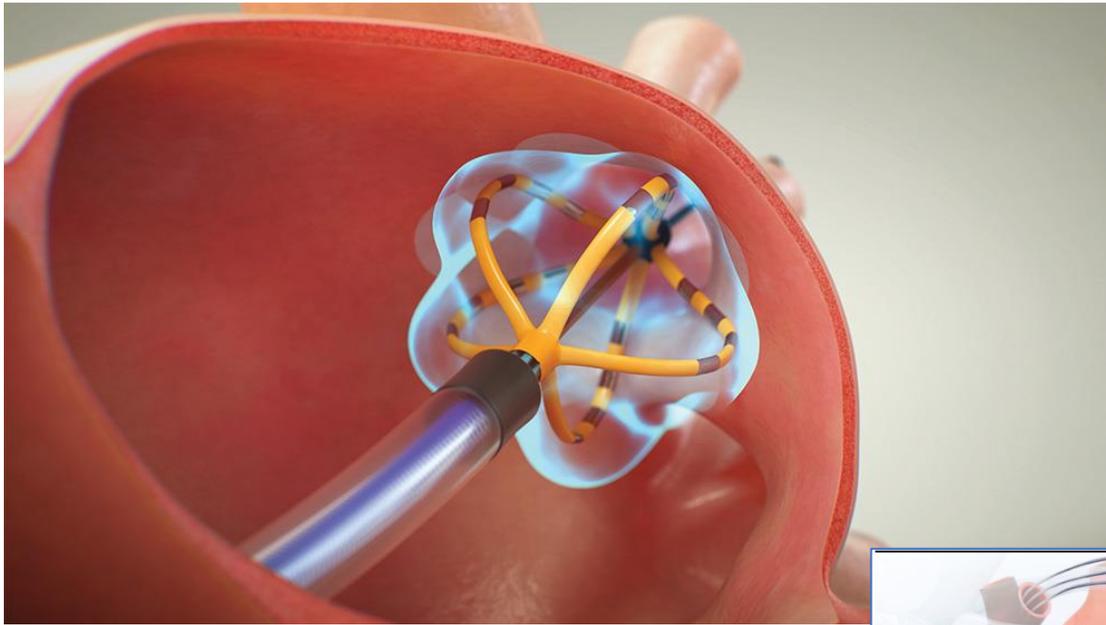


Soporte Circulatorio en Shock



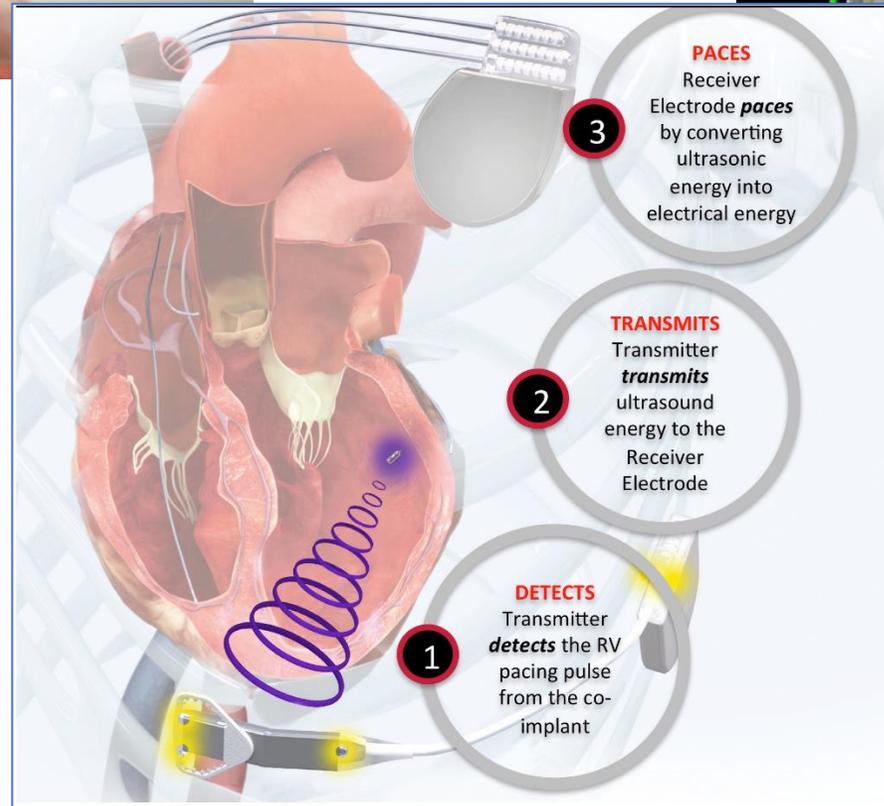
Corazon artificial, asistencias a larga

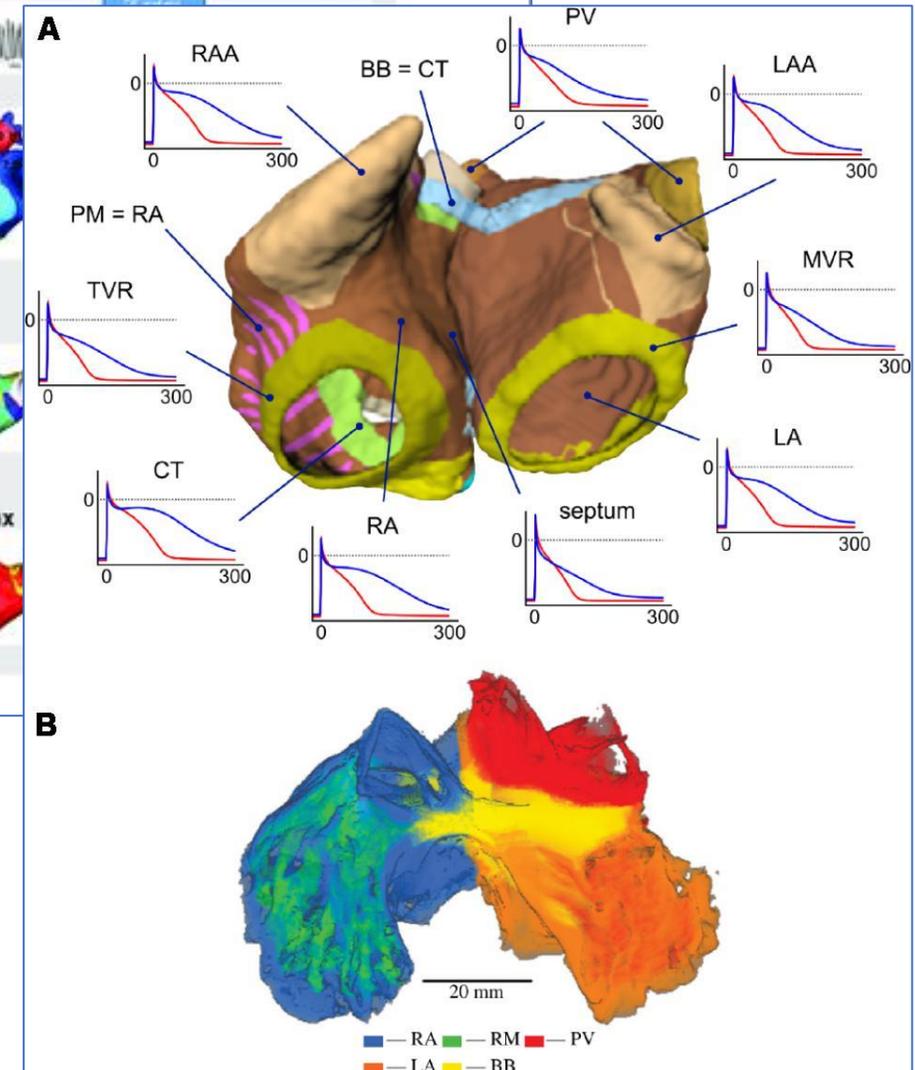
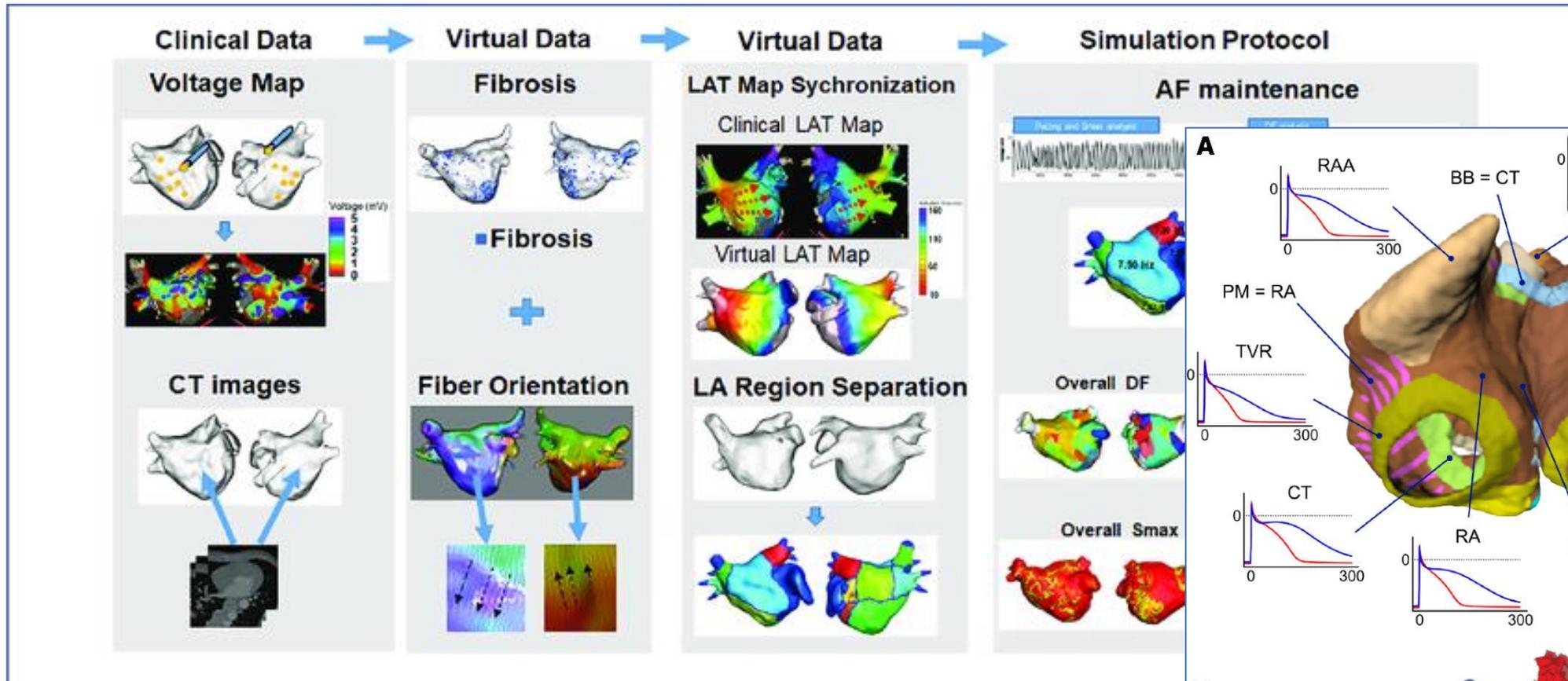




Electrofisiologia

Arritmias





RETOS

Elevados costes de los procedimientos (convencer a la administración de que el costo inicial esta compensado por los beneficios clínicos a largo plazo)

Curva de aprendizaje, necesidad de **formación especializada-colaboración multidisciplinar**, la **disponibilidad** de los dispositivos y los **criterios de selección** de los pacientes.

Problema con los equipos de Cirugía Cardíaca, asimetría plantillas / actividad. **Reconversión** necesaria.

Existe amplia **variabilidad de implementación** entre países y regiones.

Cost-effectiveness of Transcatheter Aortic Valve Implantation in Patients at Low Surgical Risk in France: A Model-based Analysis of the Evolut LR Trial

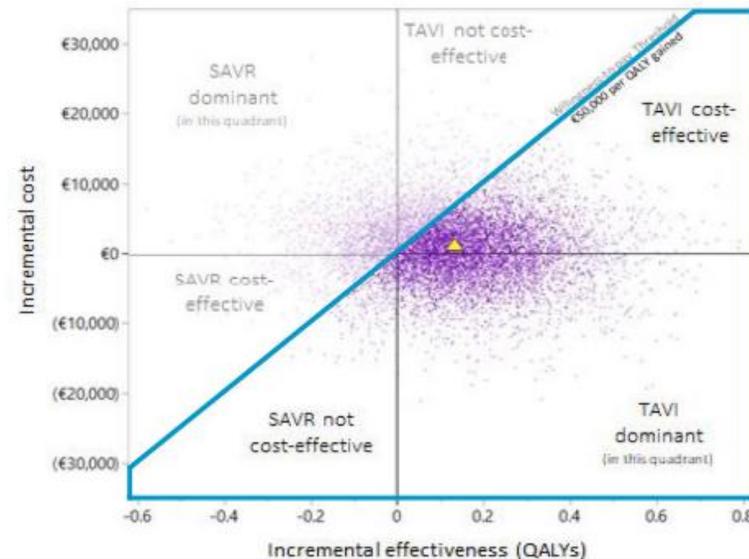
Is self-expandable TAVI a health-economically viable alternative to SAVR in patients at low surgical risk?

In a lifetime projection based on two-year data from the Evolut Low Risk trial, TAVI was found associated with:

- Increased mean survival (+0.13 life years),
- Improved quality-adjusted survival (+0.13 QALYs),
- Limited increase in lifetime cost (+€833)



rendering **TAVI cost-effective at an incremental cost-effectiveness ratio (ICER) of €6,368 per QALY gained.**



Artículo original

Variabilidad interregional en el uso de tecnologías cardiovasculares (2011-2019). Correlación con índices económicos y frecuentación y mortalidad hospitalarias

José M. de la Torre Hernández^{a,*}, Manuel Lozano González^a, Tamara García Camarero^a, David Serrano Lozano^a, Belén Cid^{b,c}, Soledad Ojeda^d, Pilar Jiménez Quevedo^e, Ana Serrador^f, Bruno García del Blanco^g, José F. Díaz^h, Raúl Morenoⁱ, Ignacio Cruz-González^{c,j}, Armando Pérez de Prado^k, Ignacio Fernández Lozano^l, Óscar Cano Pérez^{j,m} y David Cantarero Prietoⁿ

^a Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital Universitario Marqués de Valdecilla, Instituto de Investigación Sanitaria Valdecilla (IDIVAL), Santander, Cantabria, España

^b Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital Clínico Universitario de Santiago, Santiago de Compostela, A Coruña, España

^c Centro de Investigación Biomédica en Red de Enfermedades Cardiovasculares (CIBERCV), España

^d Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital Reina Sofía, Instituto Maimónides de Investigación Biomédica de Córdoba (IMIBIC), Universidad de Córdoba, Córdoba, España

^e Unidad de Cardiología Intervencionista, Servicio de Cardiología, Instituto Cardiovascular, Hospital Clínico San Carlos, Madrid, España

^f Unidad de Hemodinámica y Cardiología Intervencionista, Hospital Clínico Universitario de Valladolid, Instituto Ciencias del Corazón (ICICOR), CIBERCV, Valladolid, España

^g Unidad de Hemodinámica, Servicio de Cardiología, Hospital Universitari Vall d'Hebron, Barcelona, España

^h Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital Universitario Virgen del Rocío, Sevilla, España

ⁱ Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital Universitario La Paz, IdiPAZ, Madrid, España

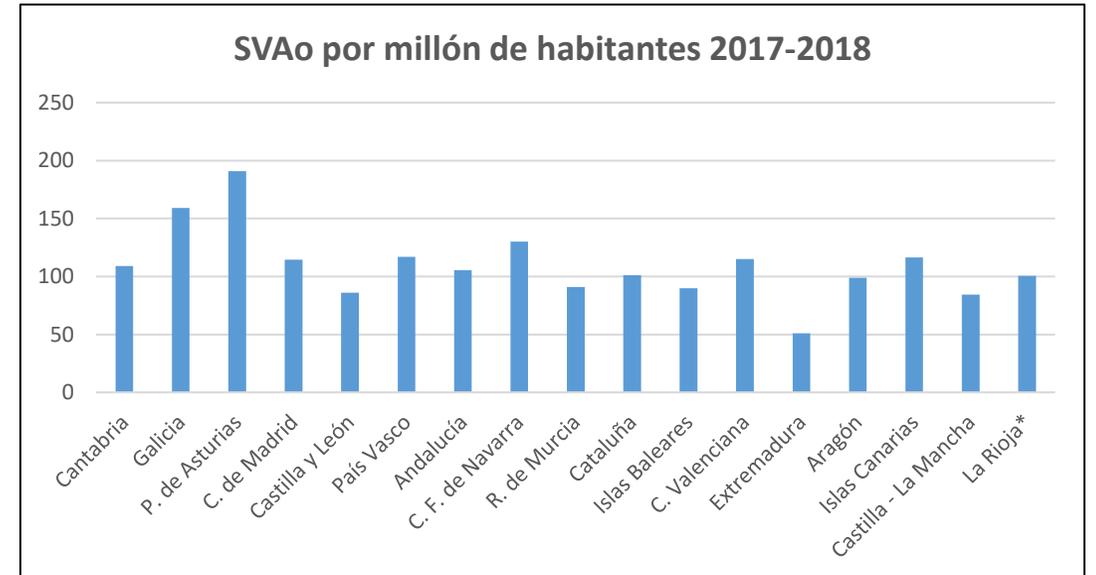
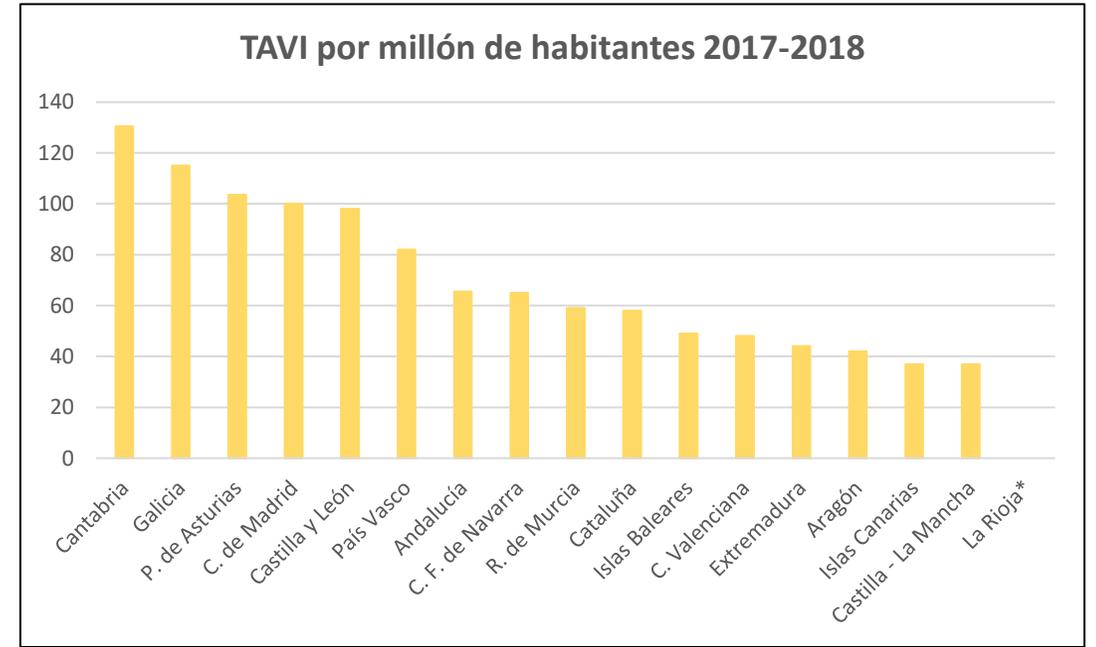
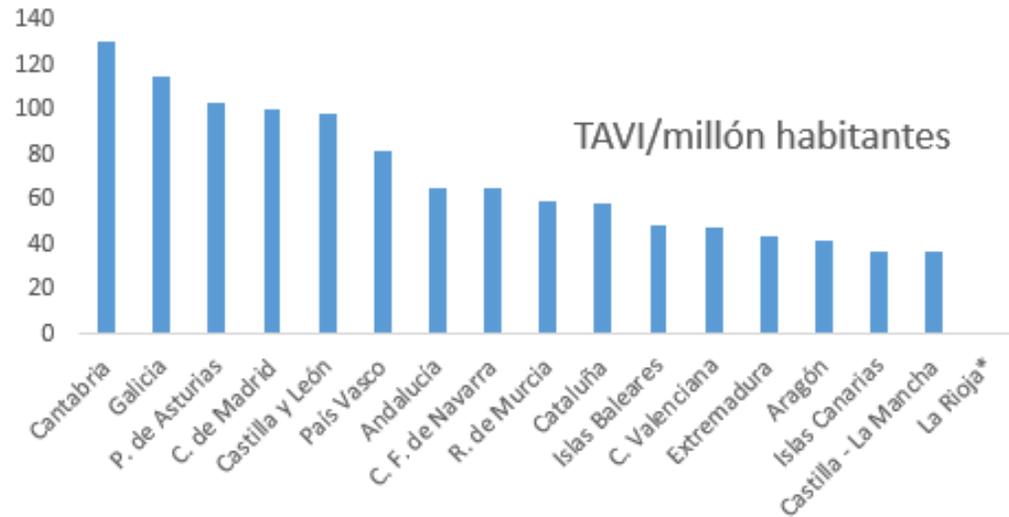
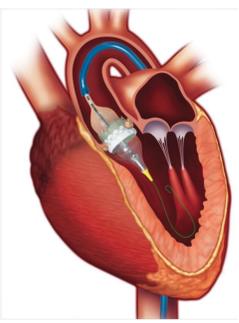
^j Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital Universitario de Salamanca, IBSAL, Salamanca, España

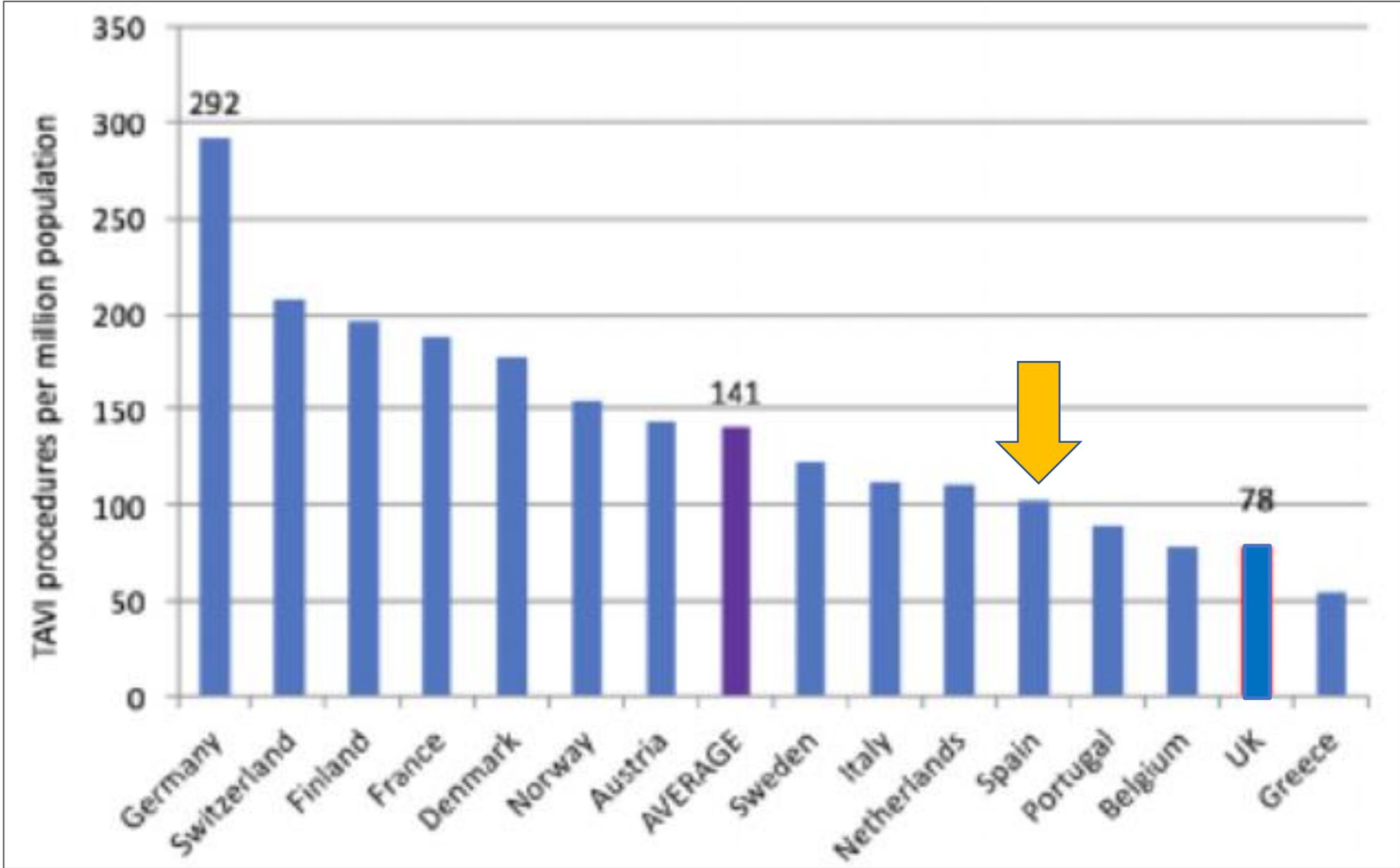
^k Unidad de Cardiología Intervencionista, Servicio de Cardiología, Hospital de León, León, España

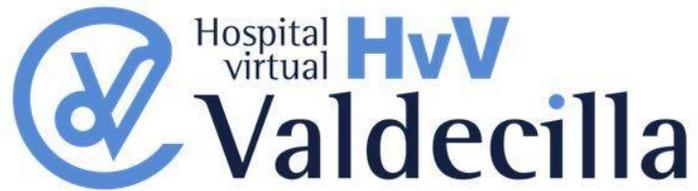
^l Unidad de Arritmias, Servicio de Cardiología, Hospital Puerta de Hierro, Majadahonda, Madrid, España

^m Unidad de Arritmias, Servicio de Cardiología, Hospital Universitario y Politécnico La Fe, Instituto de Investigación Sanitaria La Fe, Valencia, España

ⁿ Departamento de Economía, Grupo de Economía de la Salud y Gestión de Servicios Sanitarios, Universidad de Cantabria-IDIVAL, Santander, Cantabria, España







Centro de Innovación y Entrenamiento de Alto Rendimiento



<https://www.youtube.com/watch?v=rWhIQCLwGgk&t=71s>



<https://www.youtube.com/watch?v=xjzbOS1scbQ>

- #Talento
- #Tecnología
- #Simulación
- #Entrenamiento
- #Seguridad
- #Experiencia

Sistema de

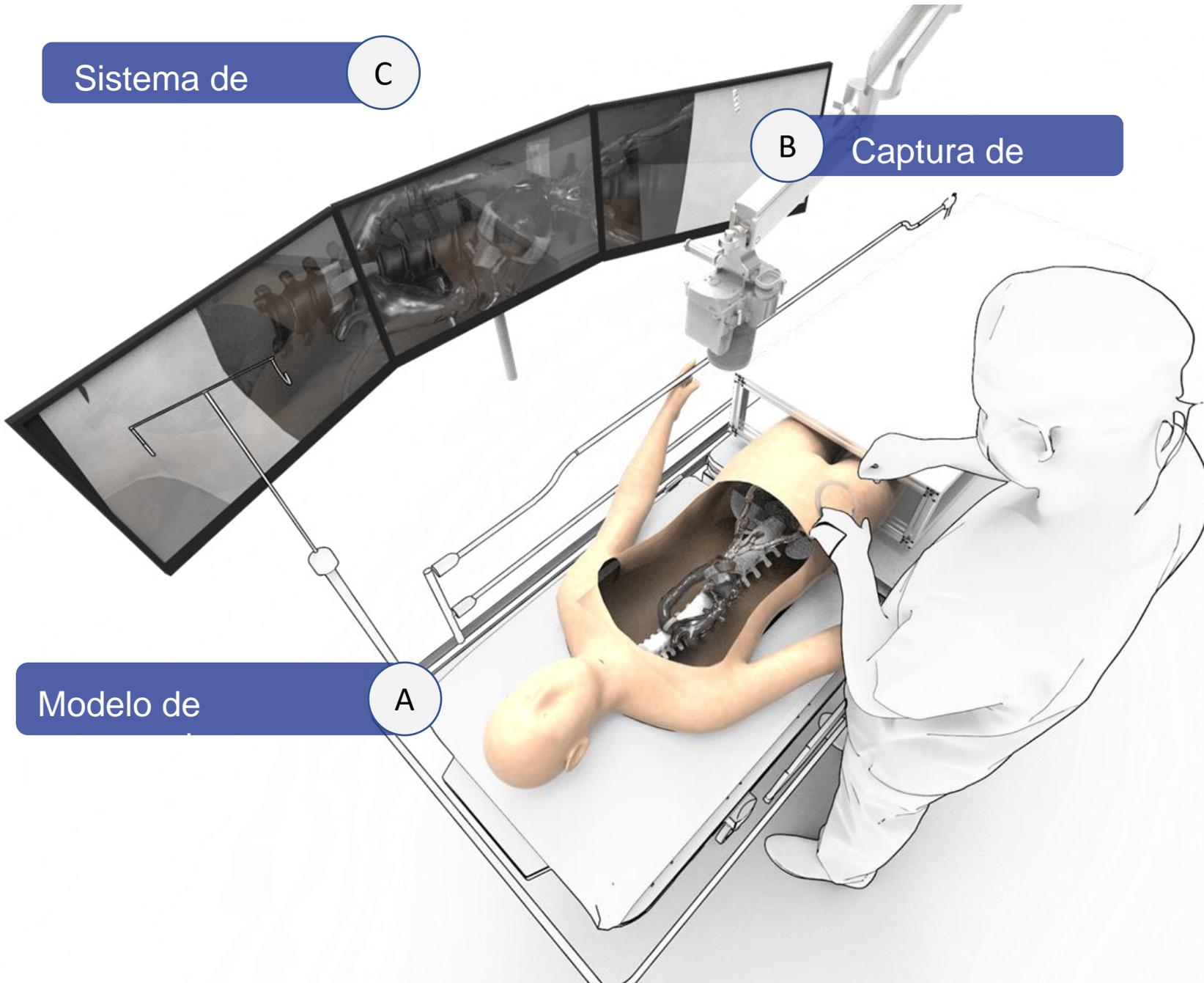
C

B

Captura de

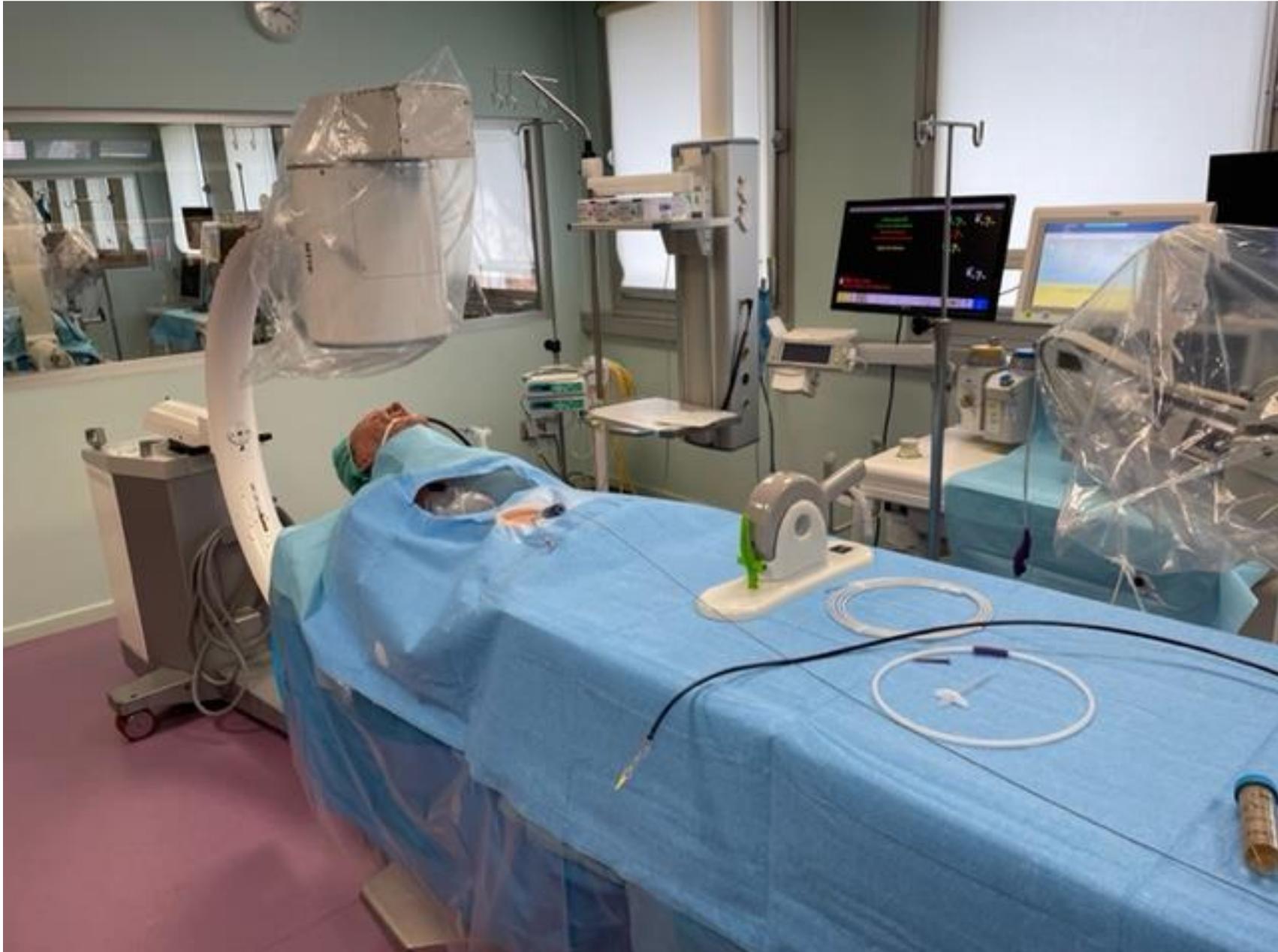
Modelo de

A



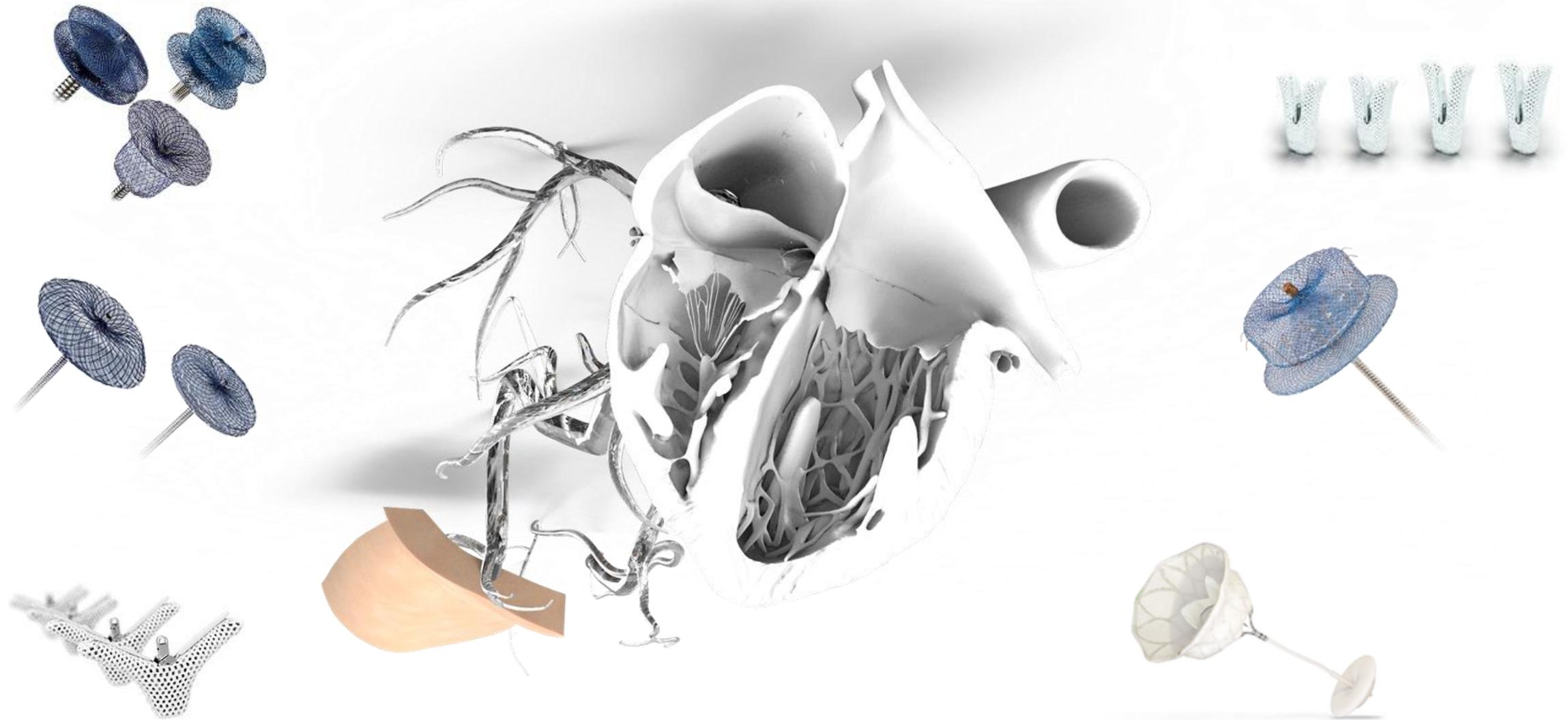
El modelo de entrenamiento **A** recrea el procedimiento desde la punción para el acceso, hasta la implantación de la válvula.

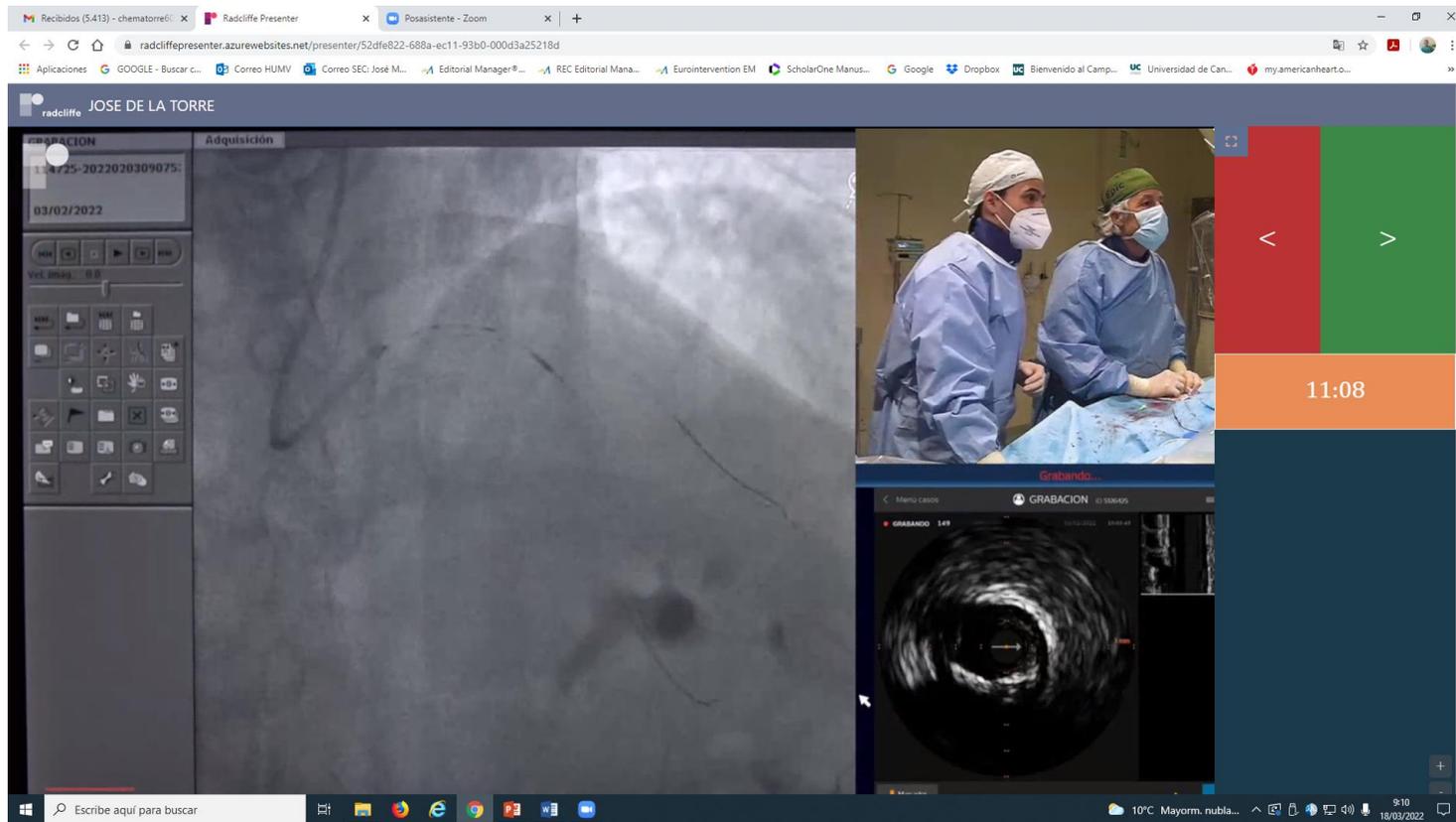
Con el objetivo de simular el procedimiento completo en un contexto realista replicando los gestos y técnica real sin las inconveniencias de la radiación, la radioscopia fue sustituida por un elemento **B** de captura de imagen que enfoca al modelo de entrenamiento **A** y se muestra en el sistema de visionado **C**.



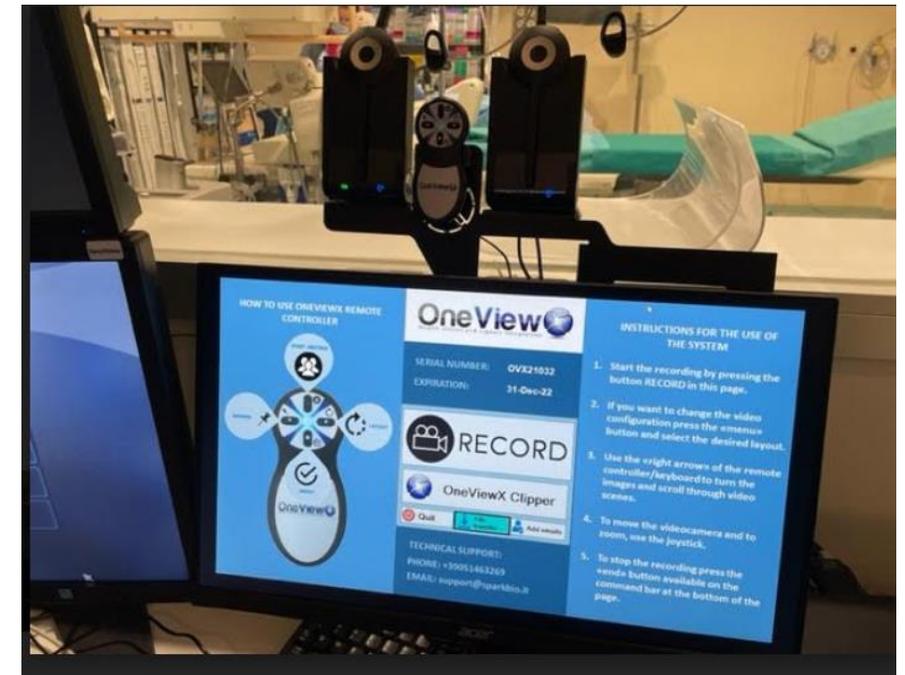
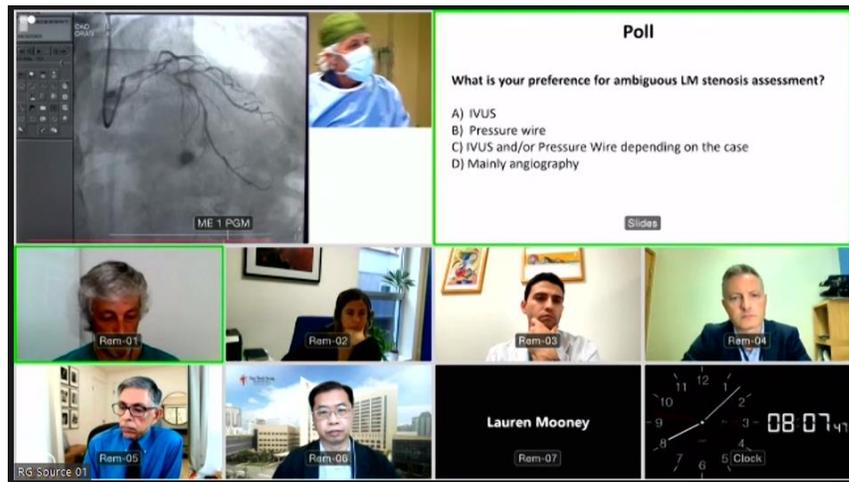


Una tecnología y expertise que permite generar patologías de manera modular





Trasmisión directa o diferida de casos en cursos internacionales (12 en últimos 4 años)

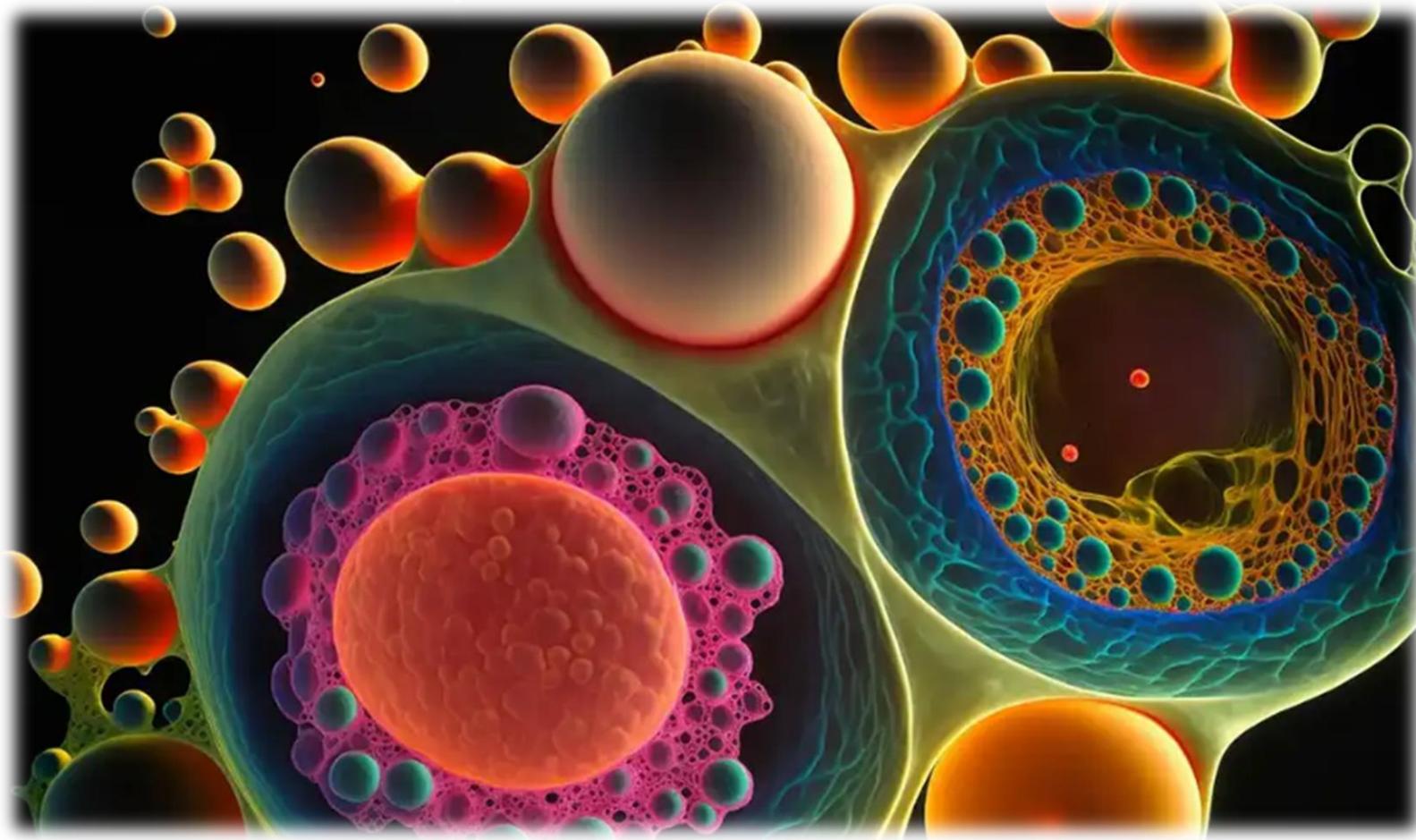


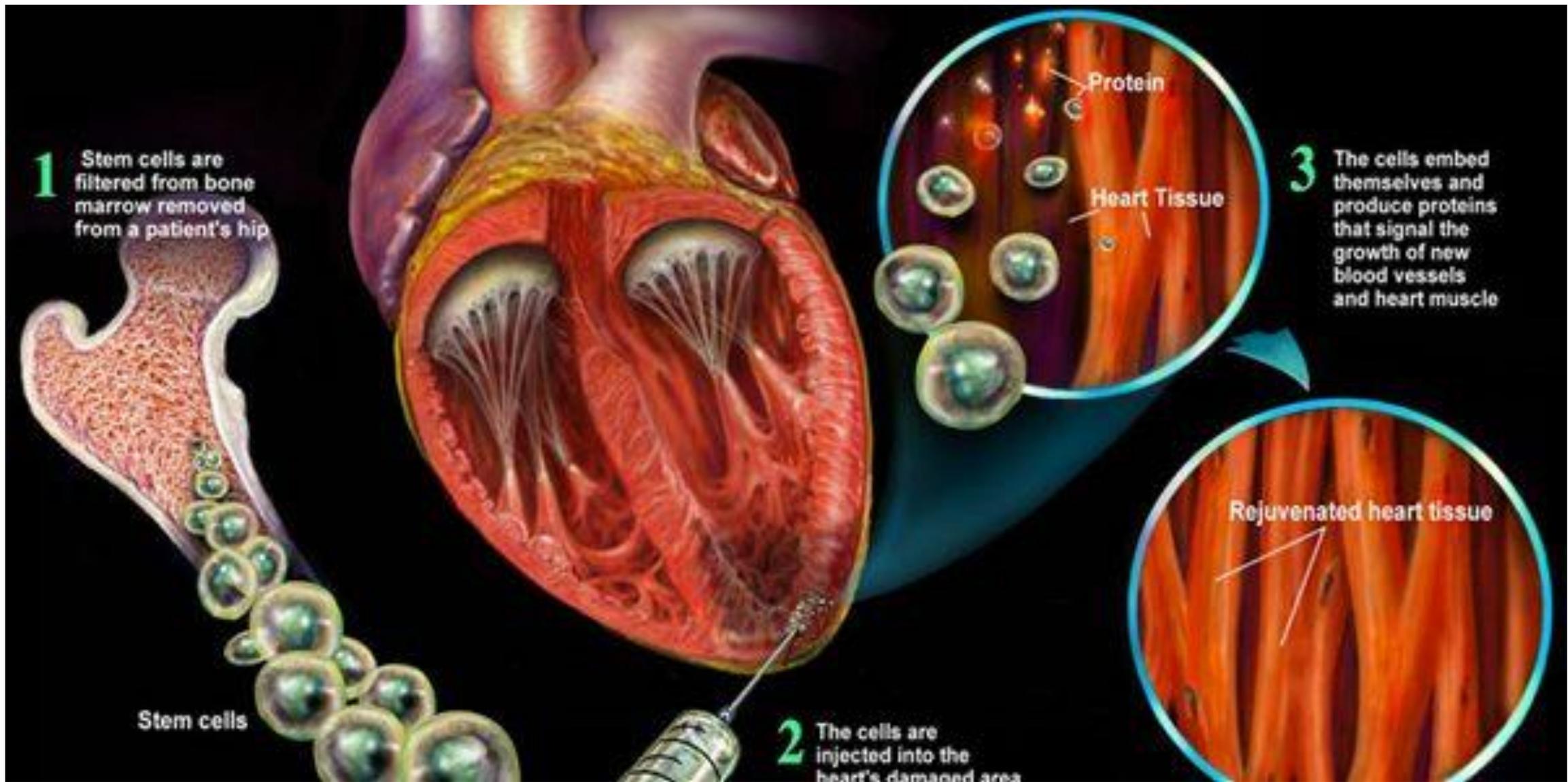
Traditional heart surgeons are becoming unemployed in UK-US Interventional Cardiology teams in continuous growth



Medicina regenerativa:

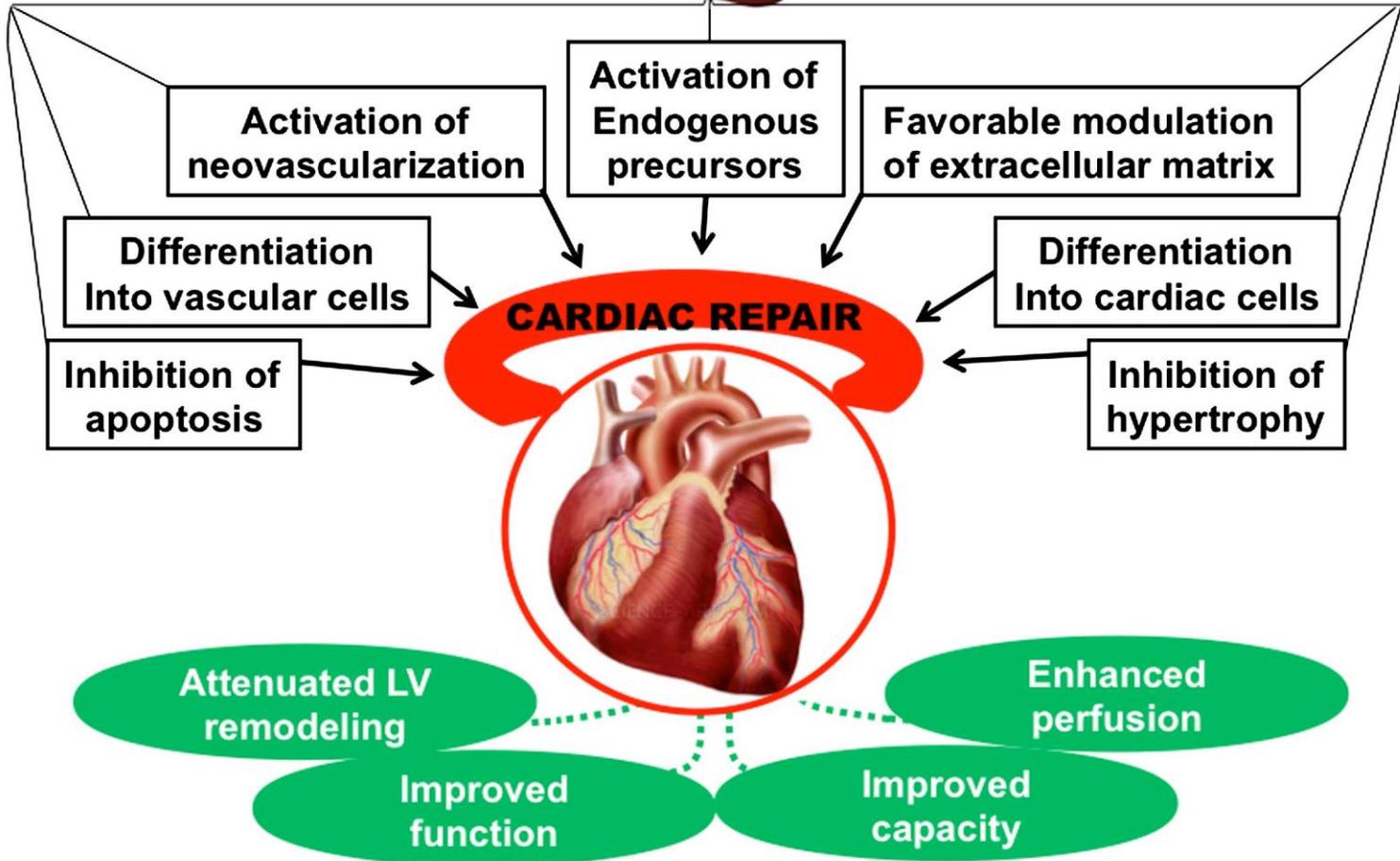
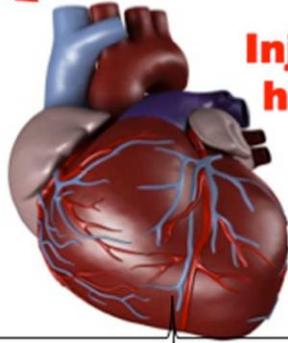
Reparar el corazón con terapias innovadoras



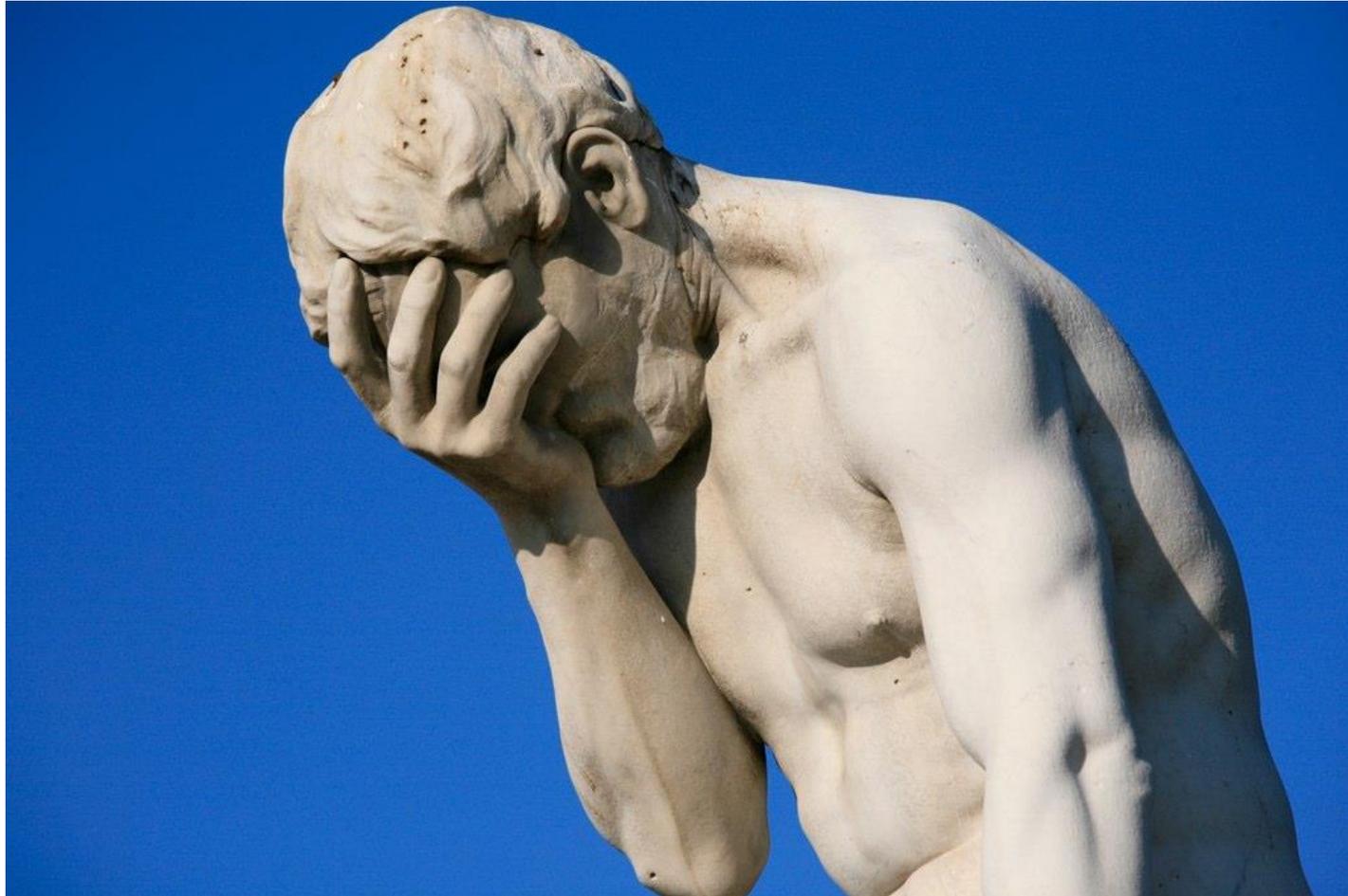


Infusion of stem cells

Injured heart



En últimas 2 décadas, el exceso de optimismo y afán de notoriedad indujo el salto precipitado a los ensayos clínicos, causando mediocres resultados, decepción, pausa-reflexión y vuelta a la investigación básica



The sad plight of cell therapy for heart failure: causes and consequences

Roberto Bolli, Xian-Liang Tang

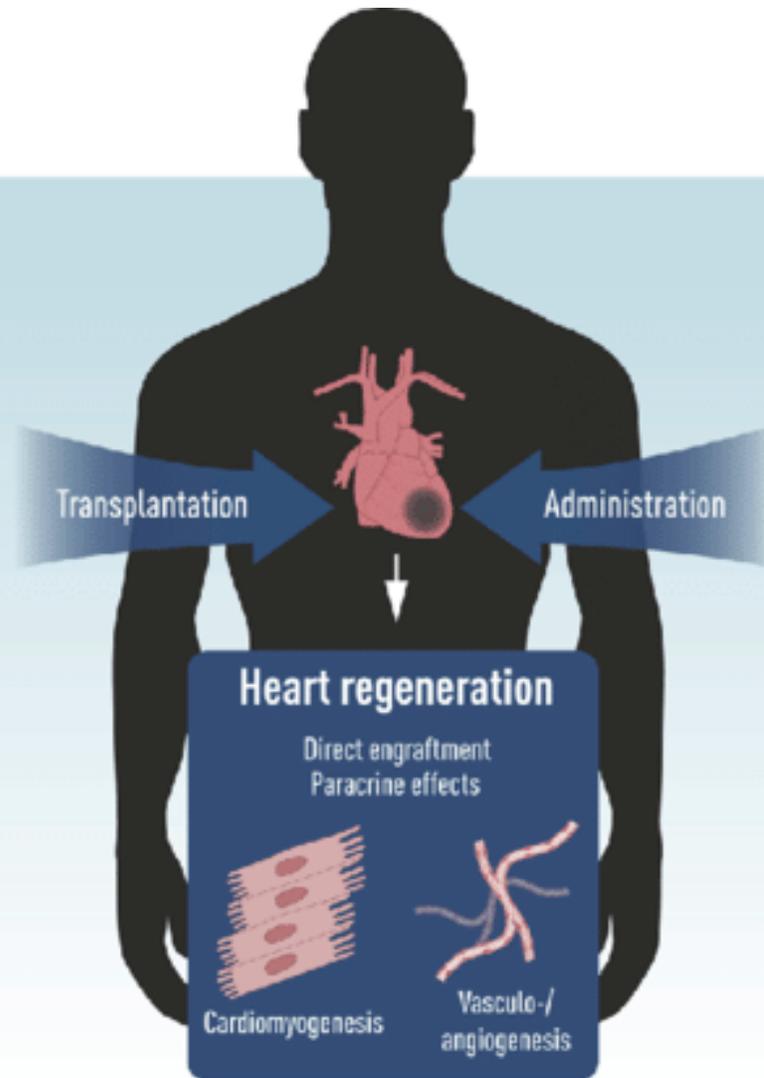
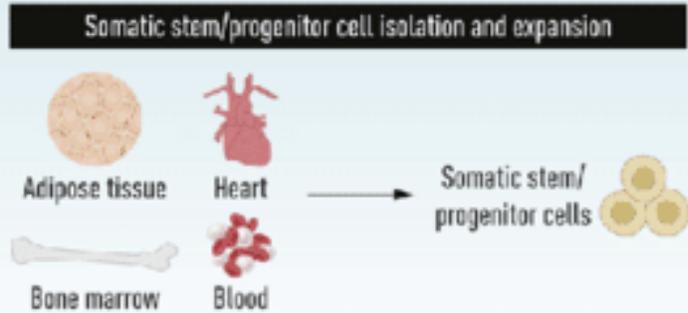
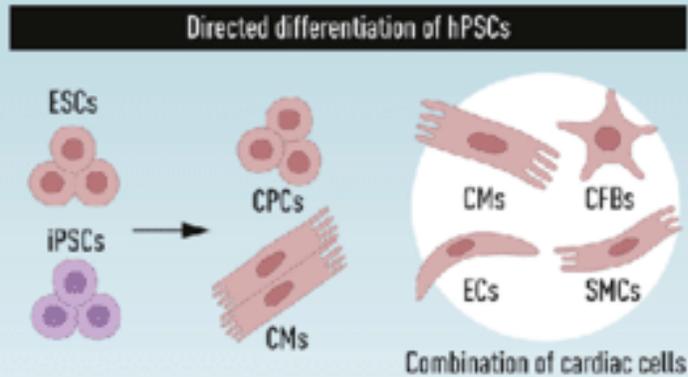
Institute of Molecular Cardiology, University of Louisville, Louisville, KY 40292, USA.

“El comportamiento gregario es la elección por defecto de la mayoría de los seres humanos, ya que es mucho más seguro y fácil seguir al rebaño que pensar por uno mismo.

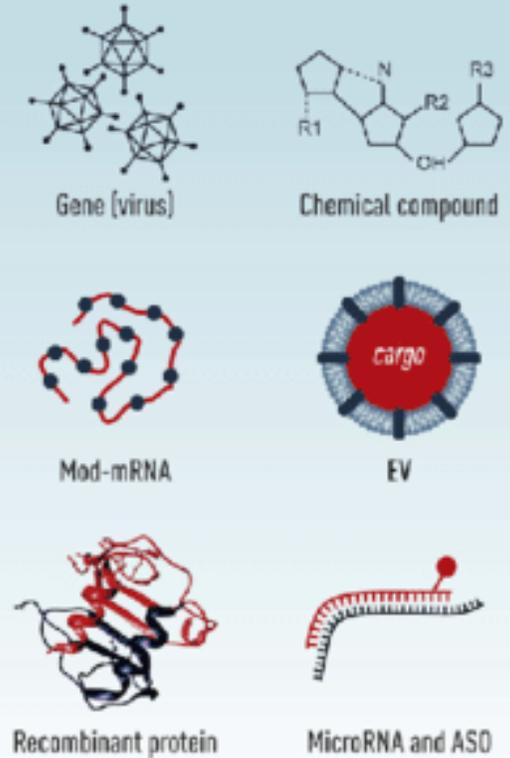
La mentalidad de rebaño, la falta de pensamiento crítico siempre fomenta el error y ha tenido consecuencias desastrosas en la historia de la ciencia.

Las percepciones sobre la terapia celular para la IC son uno de los últimos ejemplos de una mentalidad de rebaño engañosa que ha ofuscado la verdad.”

Cell-based Therapies



Cell-free Therapies



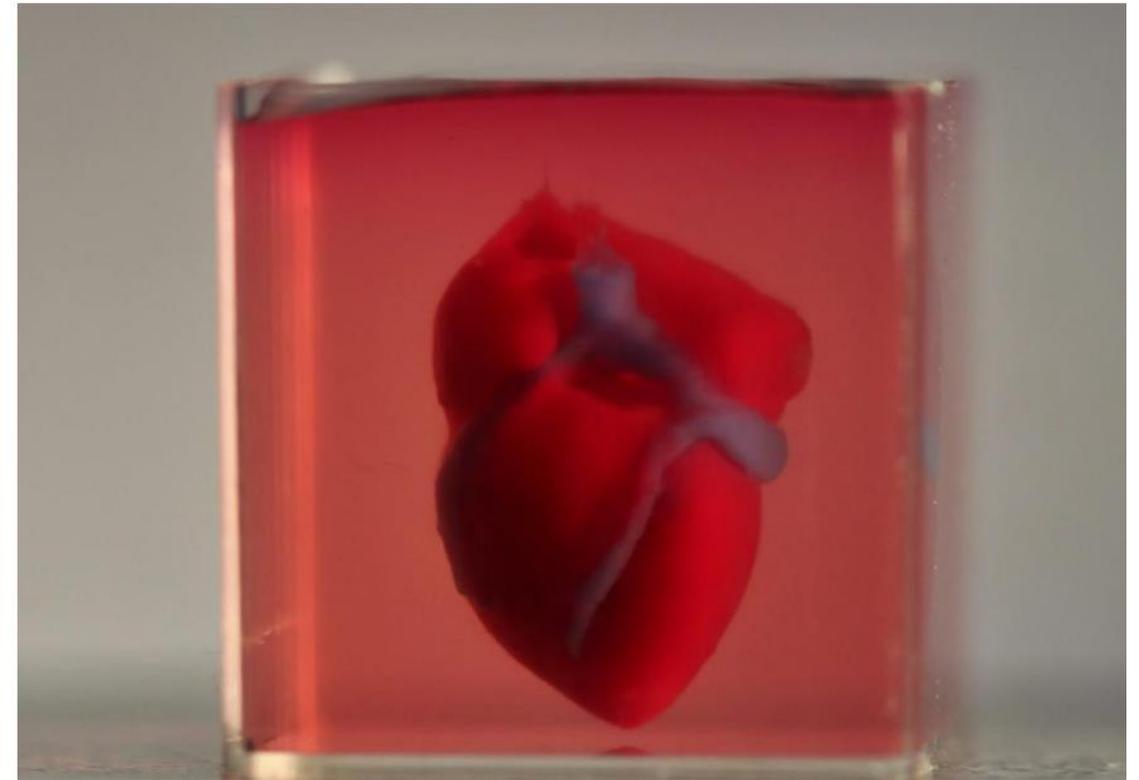
Tissue Engineered Heart Model Gives Researchers a Realistic Testing Platform

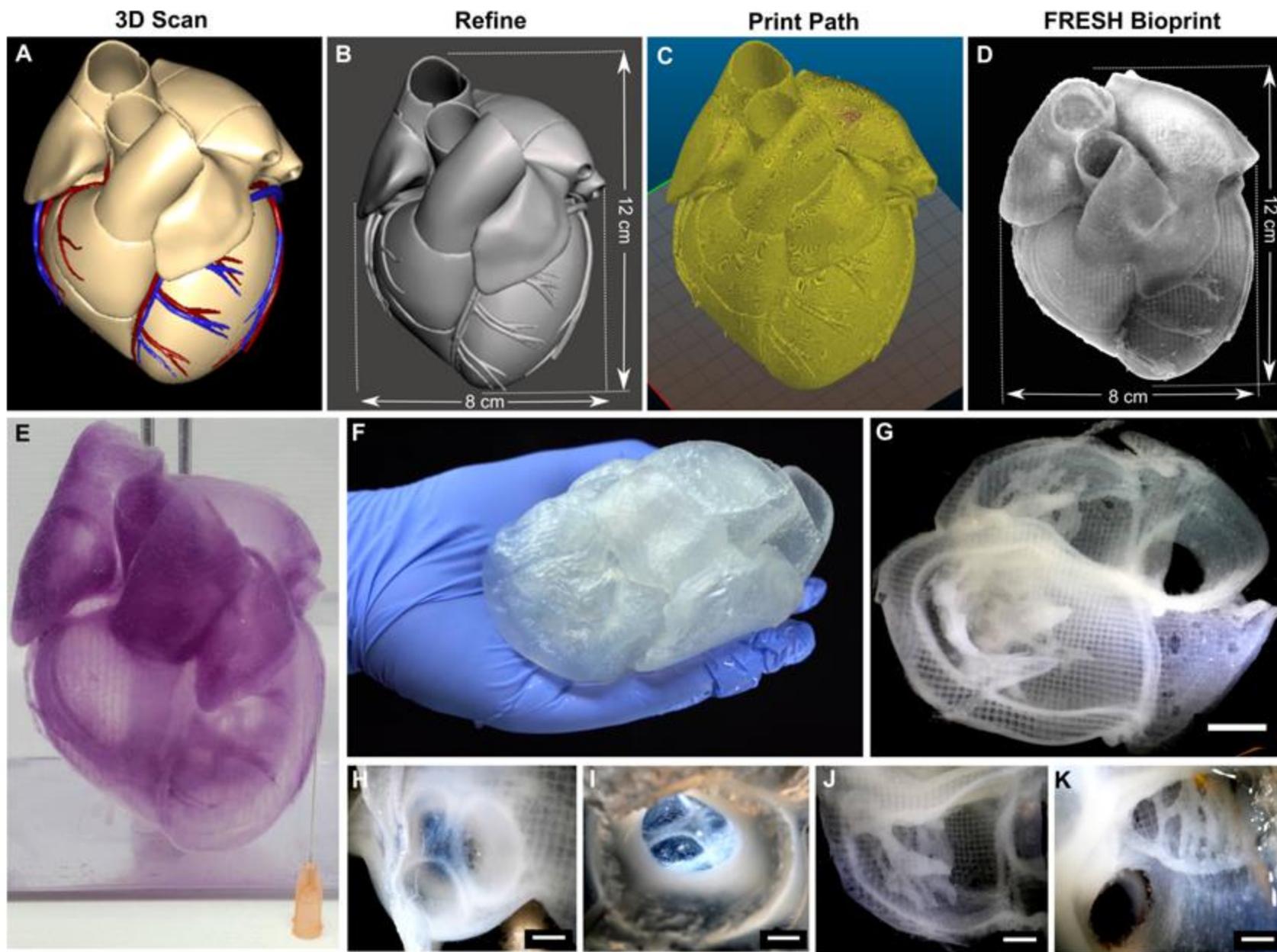
By Kenny Walter | July 25, 2018



First 3D Engineered Vascularized Human Heart Is Bioprinted

April 16, 2019





RETOS

Optimización de los tipos y fuentes celulares, la comprensión de la respuesta inmunológica a las células o tejidos transplantados, la garantía de injerto y **funcionalidad a largo plazo** y la **escalabilidad** para un uso clínico generalizado.

La traslación a la clínica requiere una compleja y larga fase de investigación preclínica.

Las **consideraciones éticas**, como el uso de **células madre embrionarias** y la **modificación genética**, también requieren una cuidadosa evaluación.

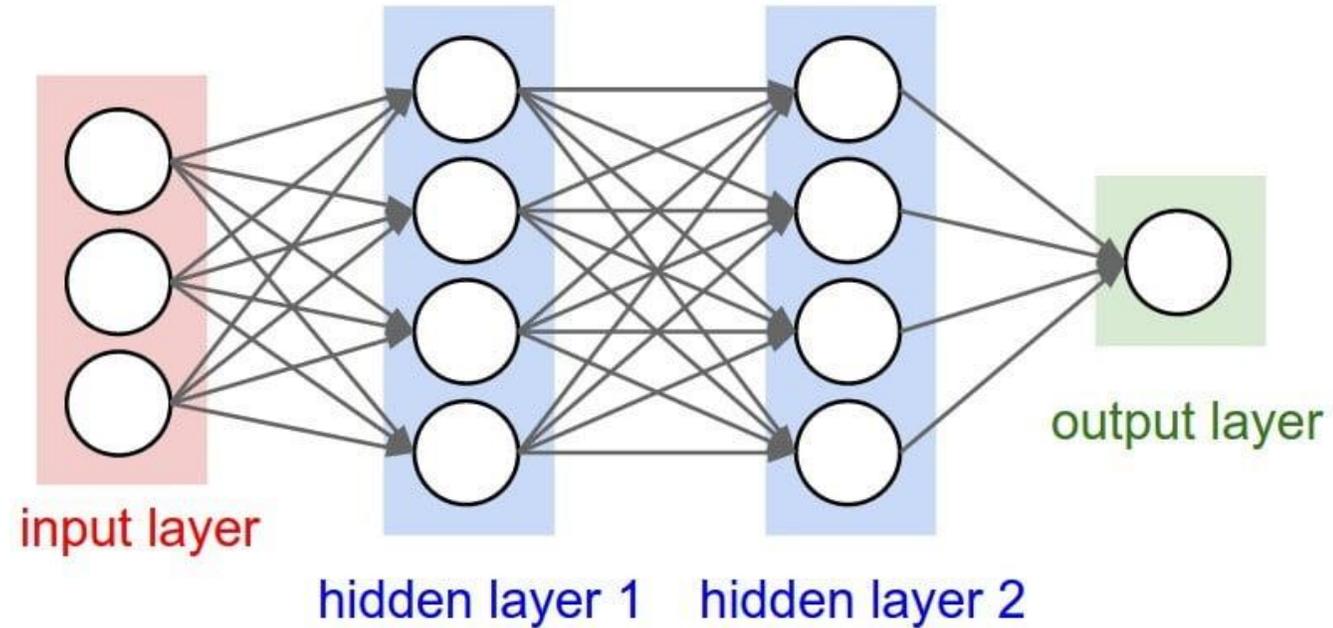
Inteligencia artificial (IA) y aprendizaje automático en cardiología





REDES NEURONALES

¿Cómo aprenden?

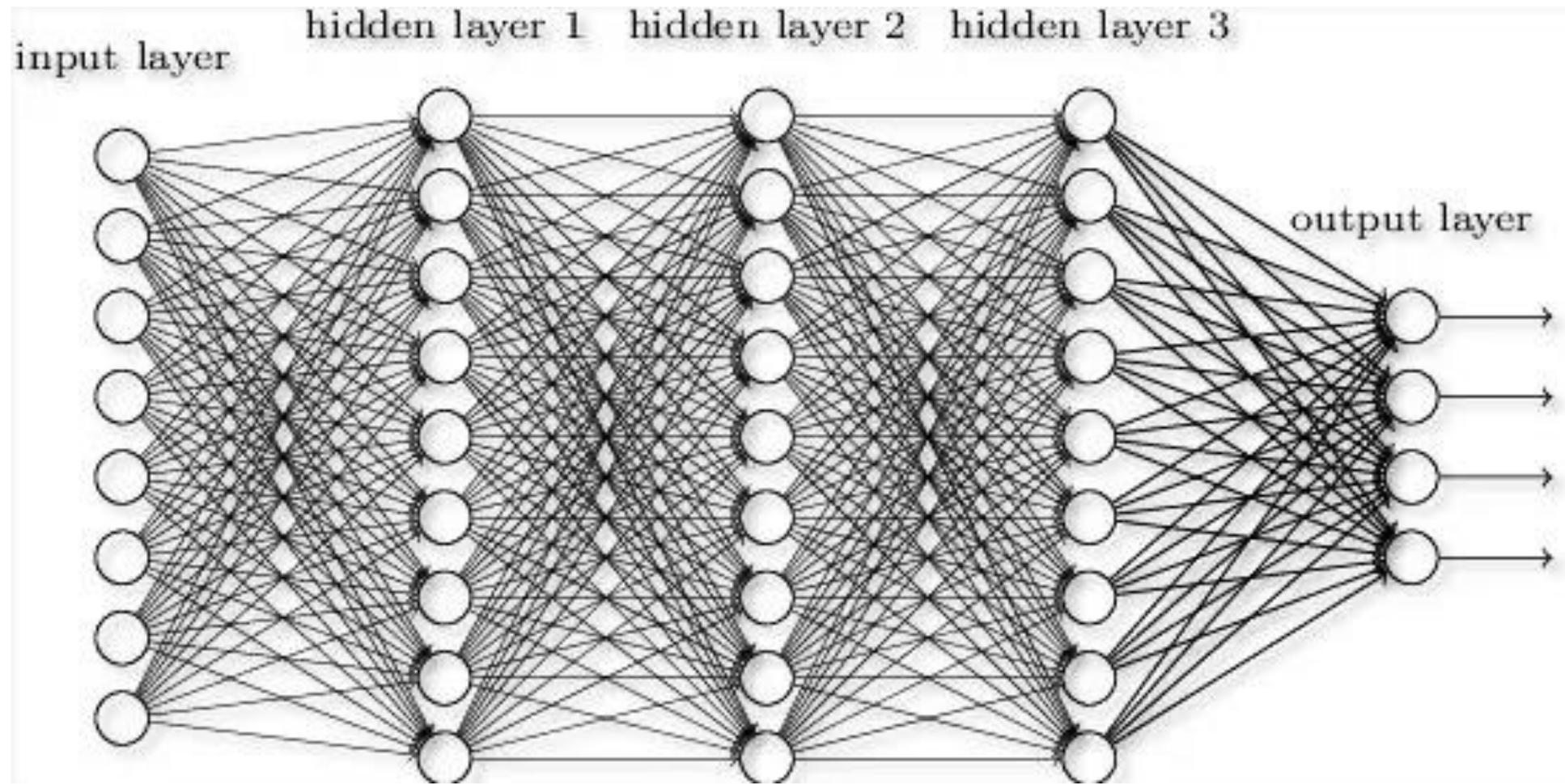


Aprender es **minimizar los errores**

Comparación con la realidad (etiquetas)

Amplitud y signo del error

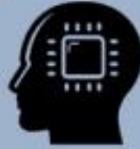
APRENDIZAJE PROFUNDO



ARTIFICIAL INTELLIGENCE

MACHINE LEARNING

DEEP LEARNING

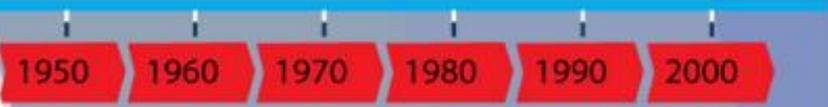
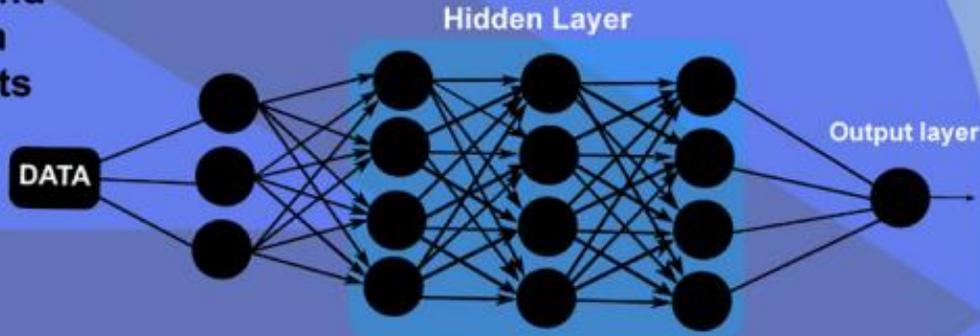


Programmes that allow machines to mimic human behaviour



Techniques that enable computers to improve at tasks without being explicitly programmed

Algorithms that adapt and learn from vast amounts of data



September 17, 2023

Artificial Intelligence in Cardiology

Where we are and where we are going

David Leone MD, FAAP
Pediatric and Adult Congenital Heart Disease
University of Washington and Seattle Children's Hospital

UW Medicine
HEART INSTITUTE

UNIVERSITY of WASHINGTON



Survey



**ARTIFICIAL
INTELLIGENCE**
in Cardiovascular Disease

23
LONDON

Royal Brompton and
Harefield hospitals **NHS**
Guy's and St Thomas'
NHS Foundation Trust

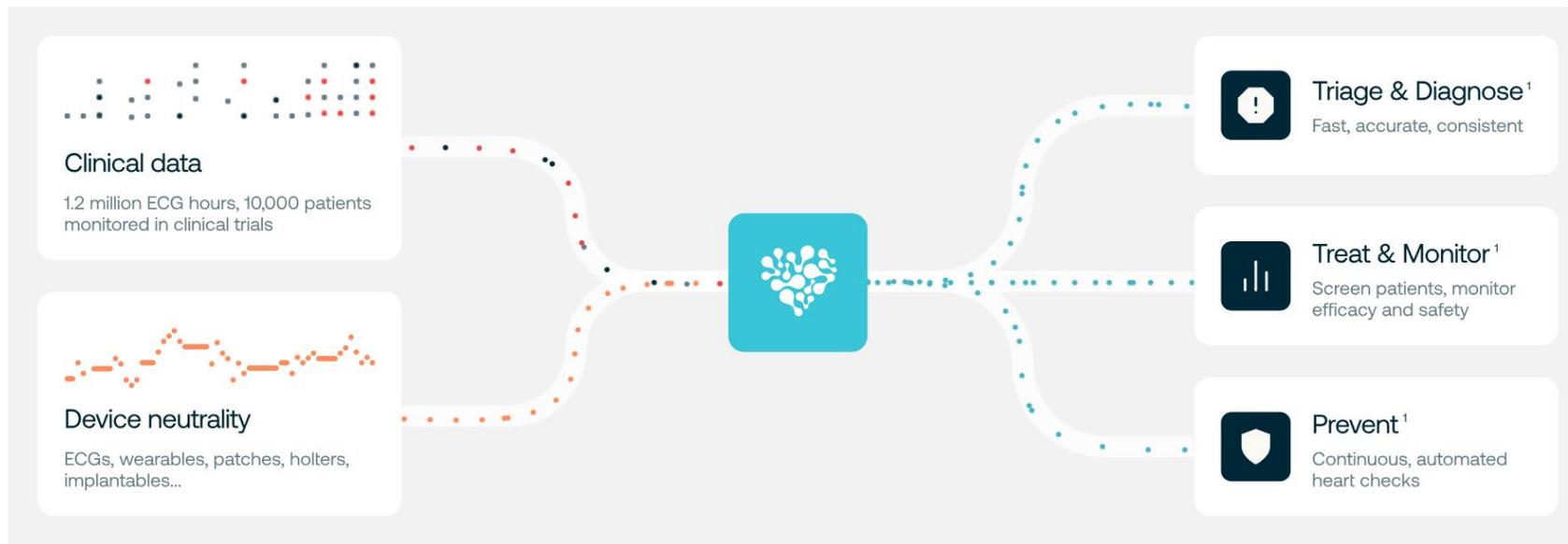
**ARTIFICIAL INTELLIGENCE AND
HEALTH TECHNOLOGIES in
Cardiovascular Disease**

**A Cardiology Update Meeting
September 20-21, 2023**



La inteligencia artificial llegará a los centros de salud para predecir problemas cardiacos

La experiencia, pionera en España y que se aplicará en Cantabria y en Madrid, es un proyecto financiado por la plataforma europea EIT Health que implicará a la Atención Primaria y a Cardiología de Valdecilla



Artificial Intelligence coming into cardiology practice near you...

...in Intervention



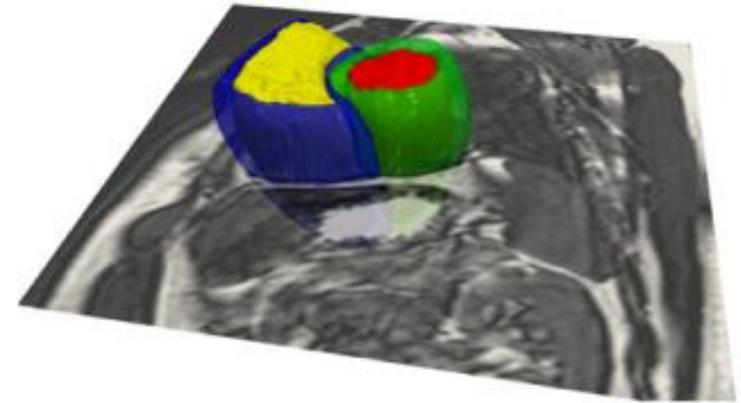
A CNN aortic pressure waveform analysis algorithm can assist with patient safety and improve diagnostic accuracy during coronary angiography

...in Electrophysiology



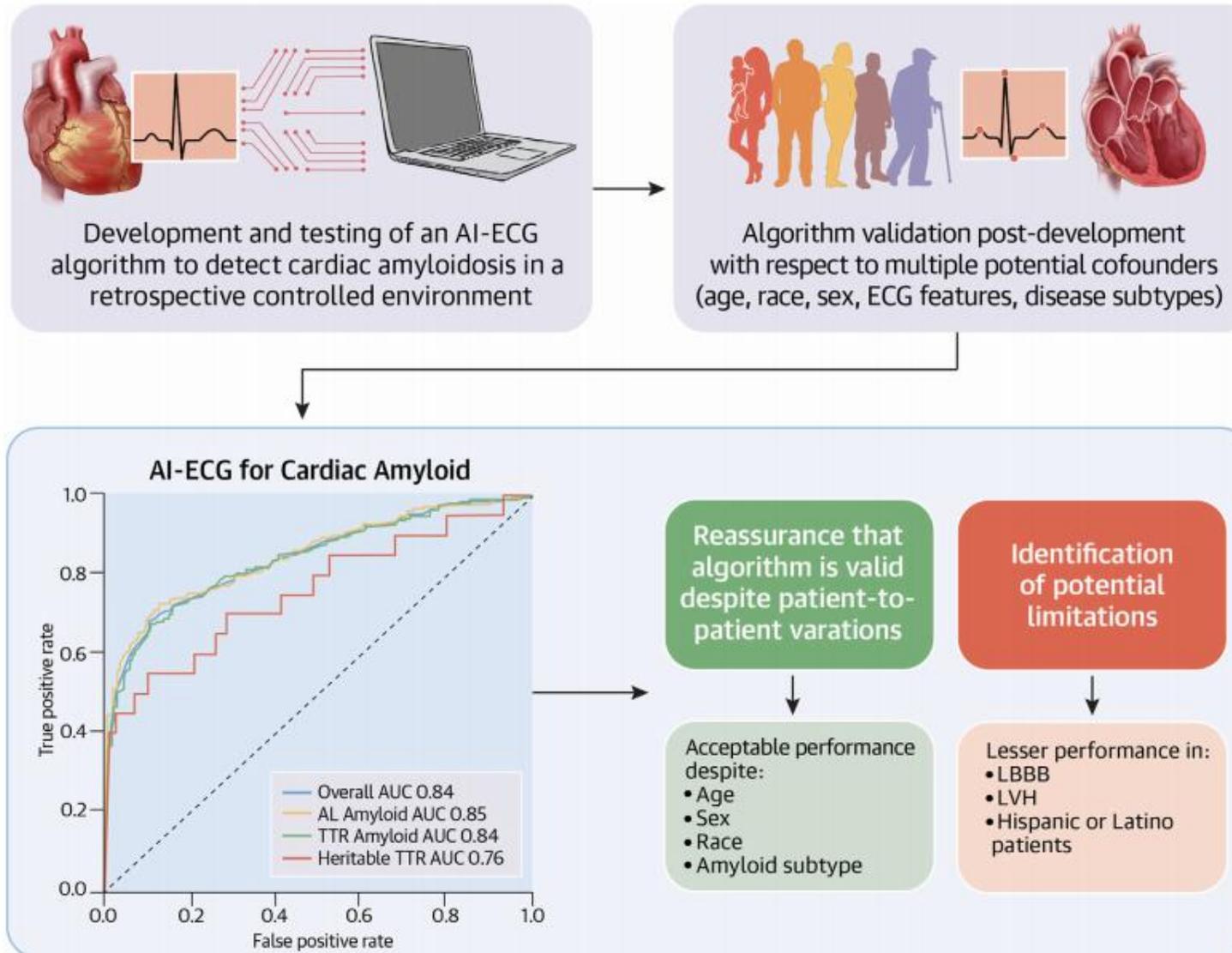
A commercially available smartwatch with an ECG sensor and a CNN algorithm can provide an inexpensive, non-invasive approach for long-term AF surveillance

...in Cardiovascular imaging

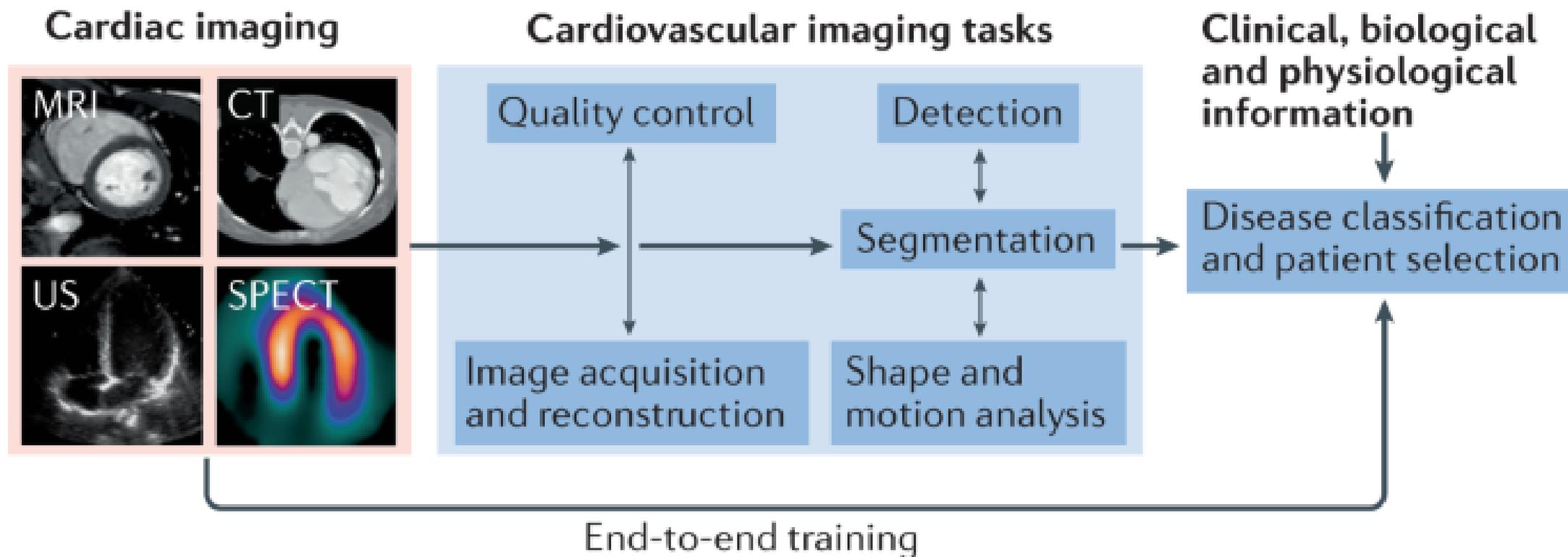


Fully automated DL approaches enable accurate and rapid CMR image segmentation and analysis of myocardial motion and deformation

Modelo ECG-IA pata detectar **Amiloidosis Cardiaca**



IA para computación de imagen cardíaca y soporte para algoritmos de decision

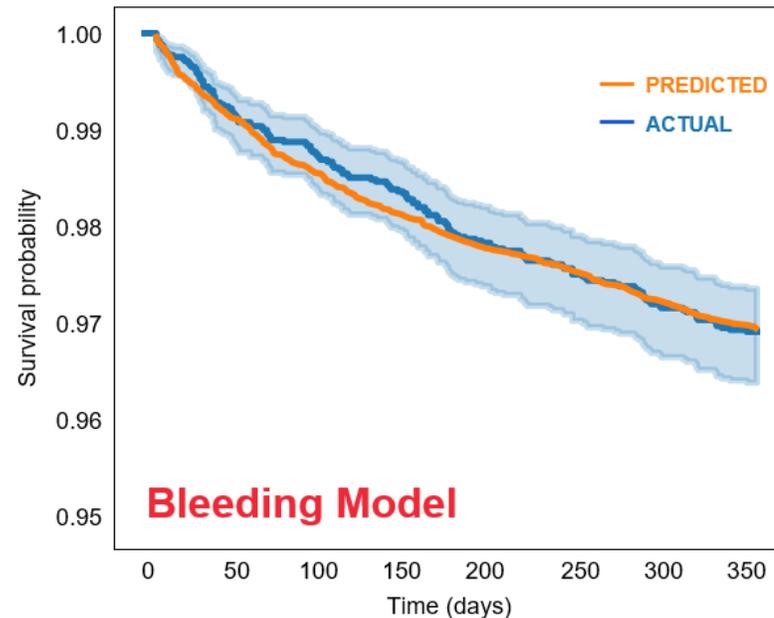
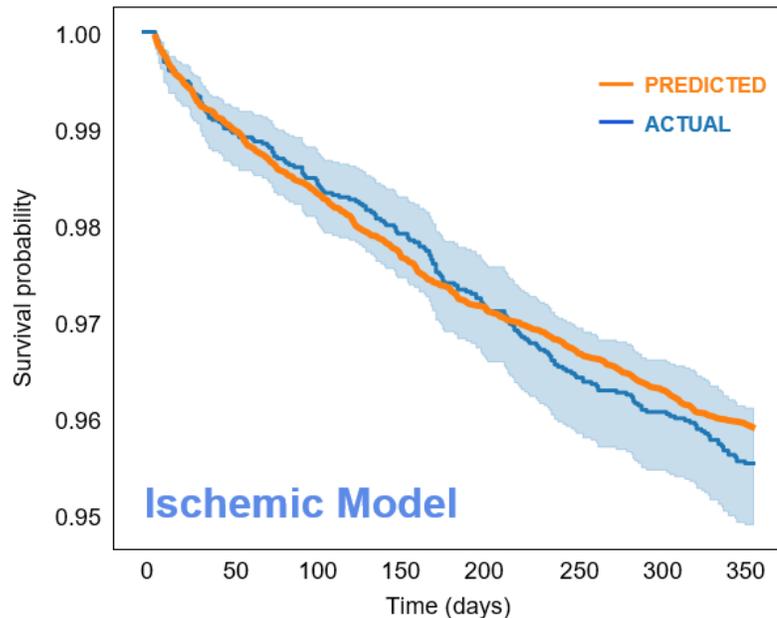


Predicting Ischemic and Bleeding Risk in Patients DAPT After PCI



The xDAPT Machine Learning Model

Actual vs. Predicted for Validation



Study Investigators:

Roxana Mehran

Marco Valgimigli

Pieter Smits

Mitchell Krucoff

Jose M. de la Torre Hernandez

Manel Sabaté

Salvatore Brugaletta

Martine Gilard

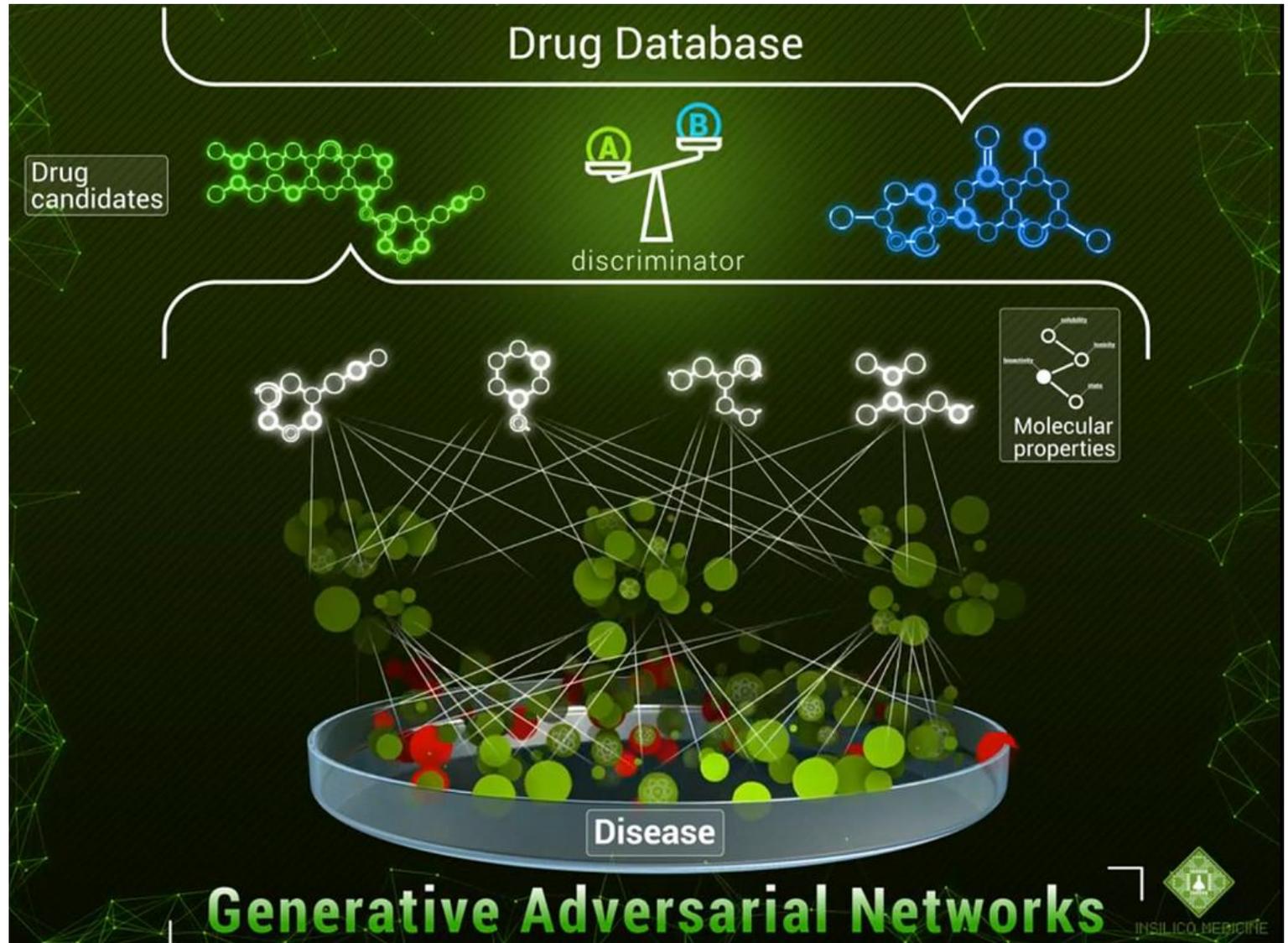
Marie-Claude Morice

Davide Cao

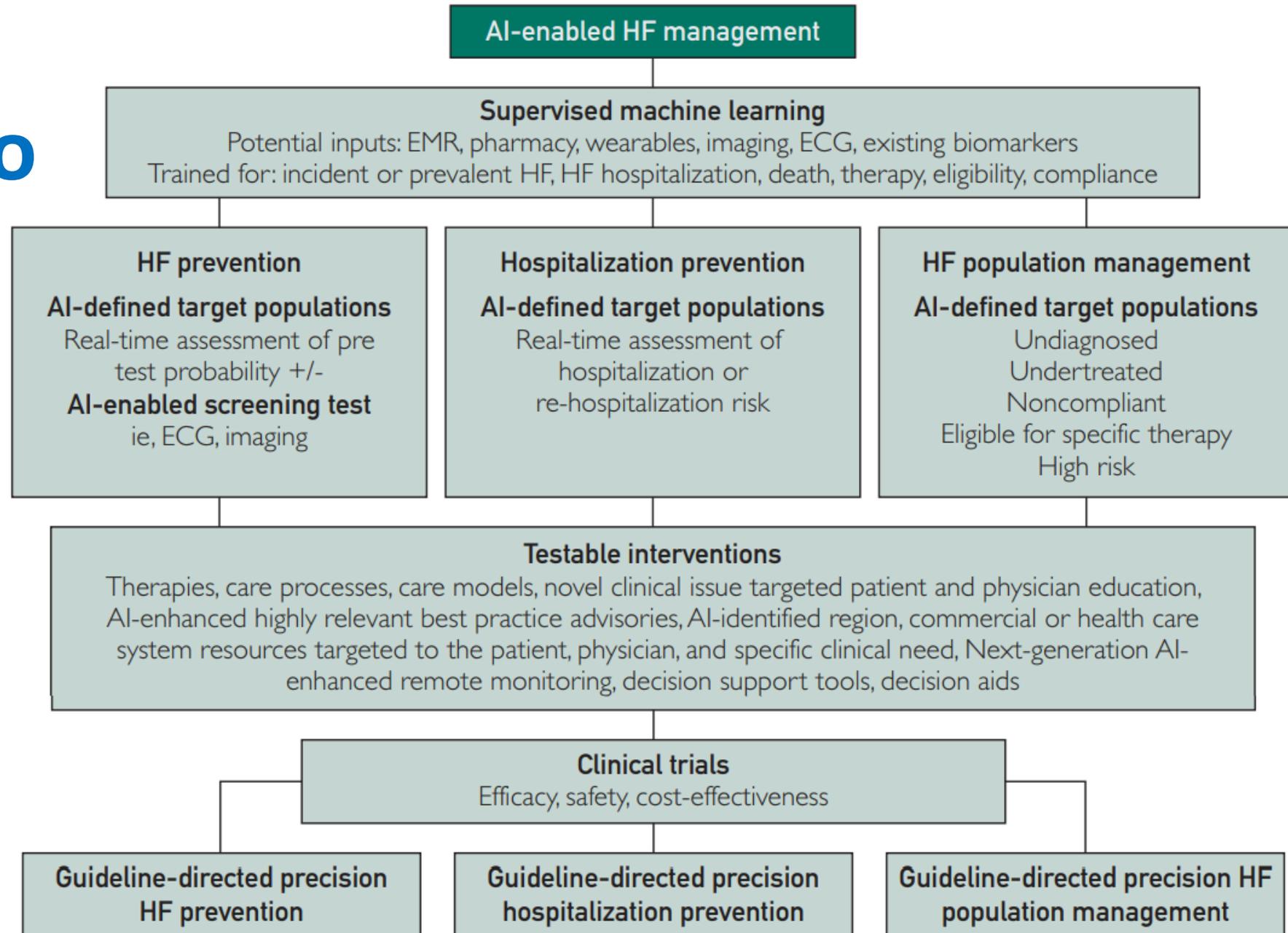


Generación de moléculas

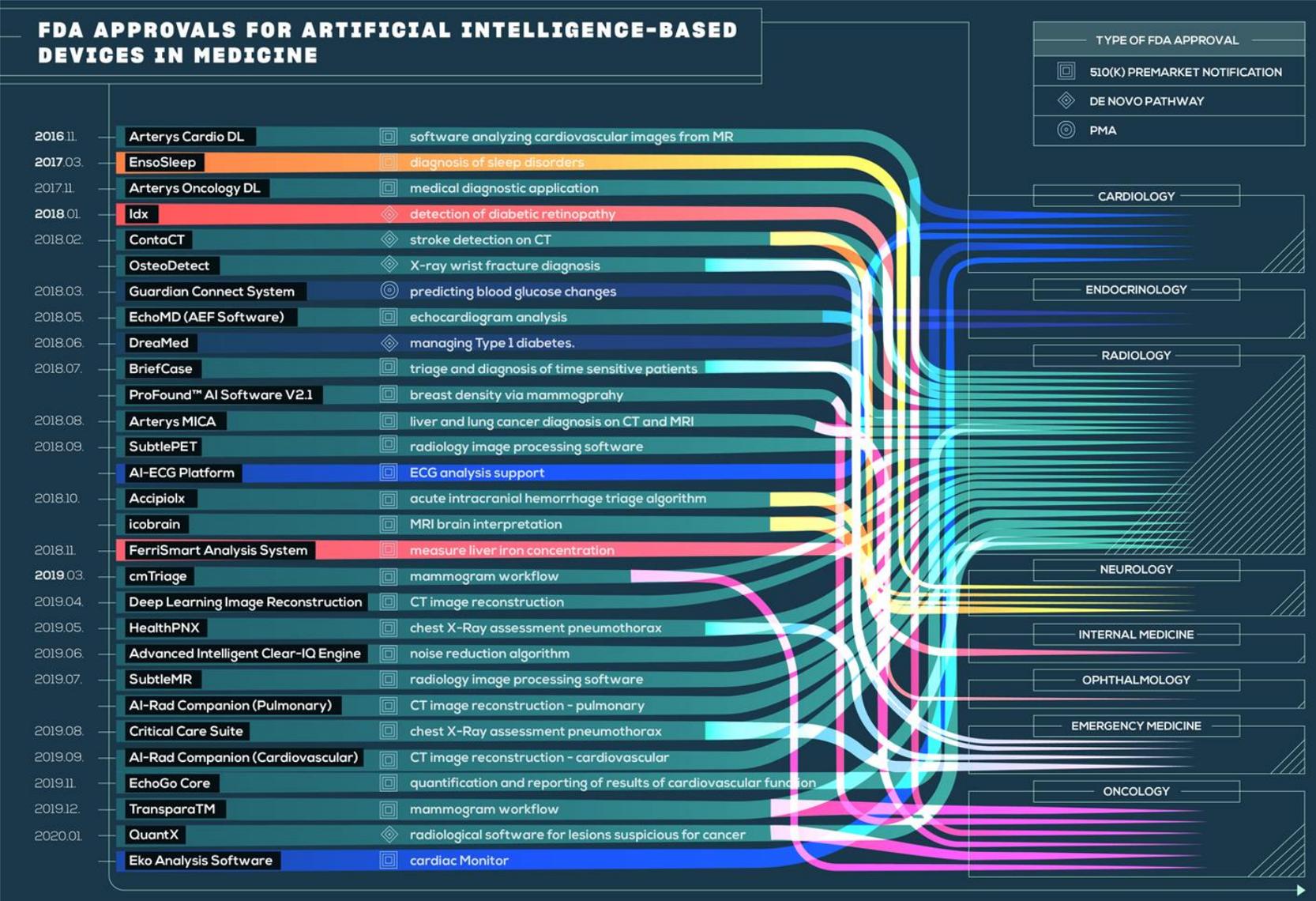
Aceleración en el diseño de fármacos



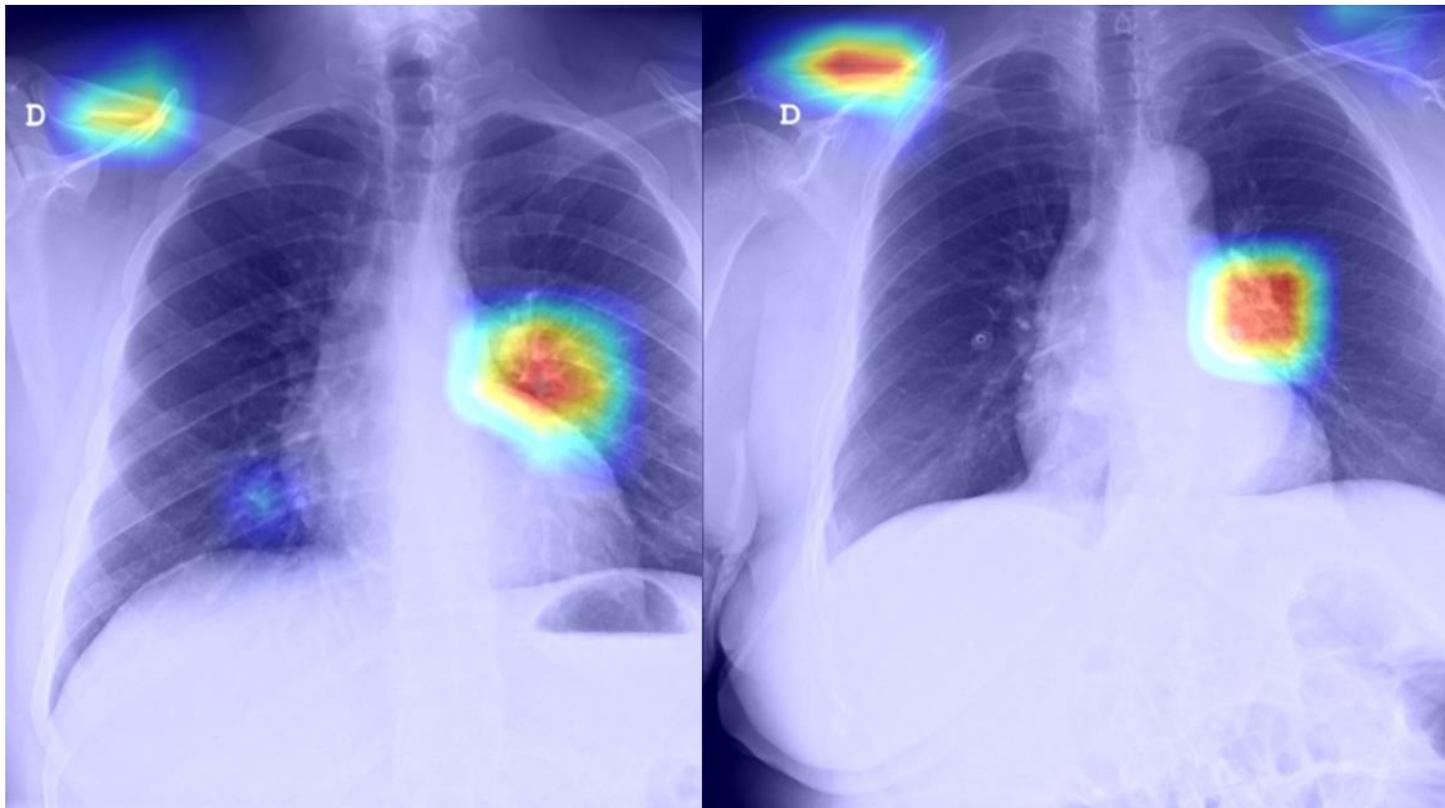
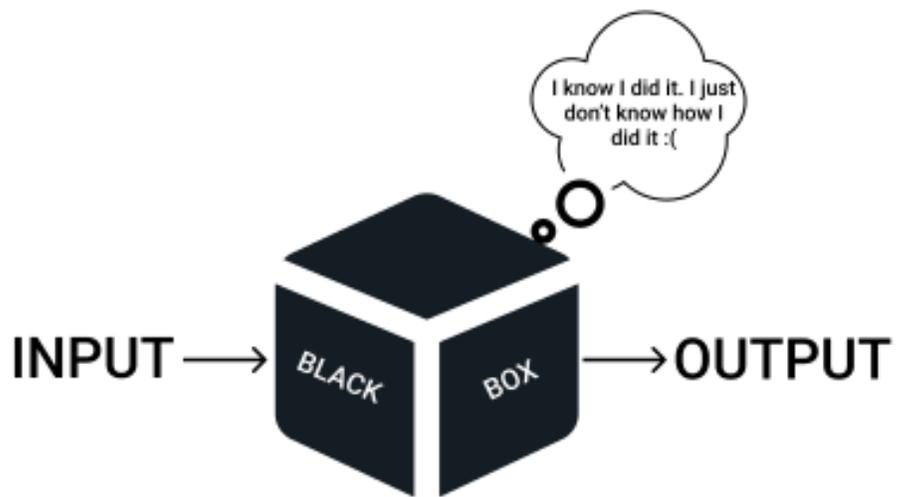
AI en el proceso clinico



Validación y utilidad clínica



INTERPRETABILIDAD



SESGOS

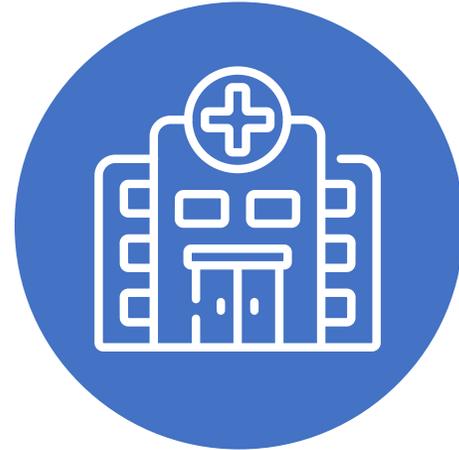
Sistema de detección de melanoma basado en IA



Sesgos → Muy relacionados con la interpretabilidad

GENERALIZACIÓN

- Máquinas de adquisición distintas, distintos protocolos, distintas calibraciones...



Hospital A



Hospital B

Generalización → Muy relacionada con los sesgos

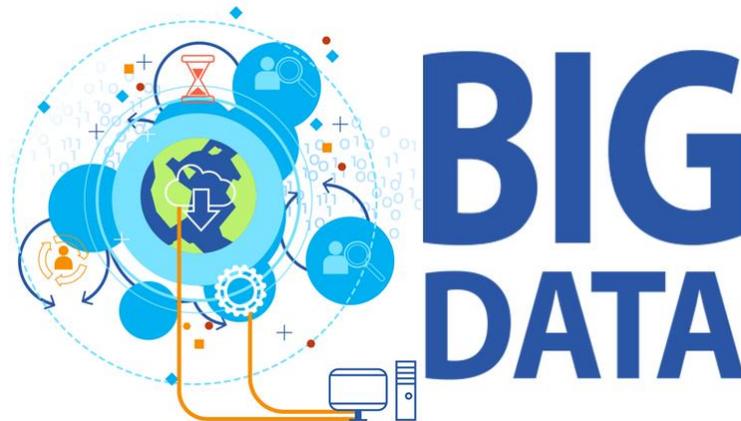
... Y OTROS PROBLEMAS A RESOLVER

Seguridad

Privacidad

Interoperabilidad

**Aspectos legales
RESPONSABILIDAD**



RETOS

Fiabilidad y seguridad.

Explicabilidad-Interpretabilidad (evitar “black-box”).

Privacidad y seguridad.

Asuntos **legales**, como la **responsabilidad profesional** derivada de su aplicación en decisión clínica.

Formación de los profesionales sanitarios, interacción con desarrolladores.

WILL DIGITAL HEALTH TECHNOLOGY REPLACE PHYSICIANS?

DIGITAL HEALTH TECHNOLOGIES WILL PLAY A LIMITED ROLE IN THESE PROFESSIONS MOSTLY SERVING AS AUXILIARY TOOLS.

DIGITAL HEALTH TECHNOLOGIES WILL HAVE AN IMPACT ON THESE PROFESSIONS BUT IT WON'T CHANGE THEIR INTERACTION-BASED NATURE.

REPETITIVE
(A LARGE PART OF THE JOB IS THE SAME EVERY DAY)

CREATIVE
(SOMETHING NEW HAPPENS EVERY DAY)

INTERACTION-BASED
(TALKING WITH THE PATIENT IN PERSON OR REMOTELY)

DATA-BASED
(DEALING WITH DATA ABOUT OR DERIVED FROM THE PATIENT)

MANY REPETITIVE COMPONENTS OF THE JOBS WILL BE REPLACED BY TECHNOLOGIES TO CREATE SPACE FOR CREATIVE TASKS.

THESE PROFESSIONS WILL BE HEAVILY DEPENDENT ON DIGITAL HEALTH TECHNOLOGIES, MEDICAL PROFESSIONALS WILL WORK WITH THEM ON A DAILY BASIS.



FUTURE TRENDS

DEEP MEDICINE

HOW ARTIFICIAL
INTELLIGENCE
CAN MAKE
HEALTHCARE
HUMAN AGAIN

ERIC TOPOL

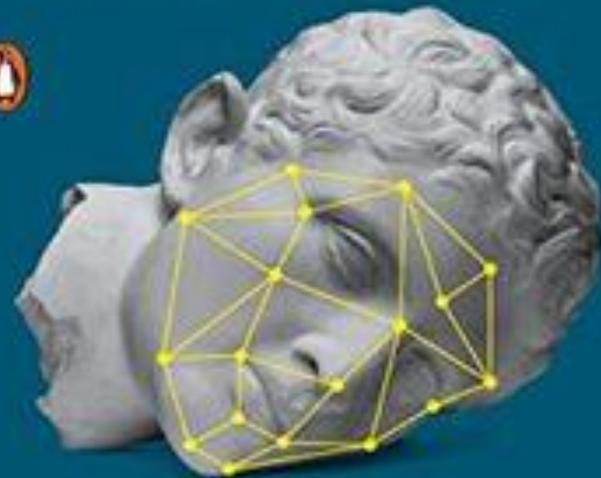
With a foreword by
ABRAHAM VERGHESE,
author of Cutting for Stone



"The most important book I have read in quite some time."
— Daniel Kahneman

Human Compatible

ARTIFICIAL INTELLIGENCE
AND THE
PROBLEM OF CONTROL



Stuart Russell

Dispositivos portables (wearables) y monitorización remota para la atención cardiovascular

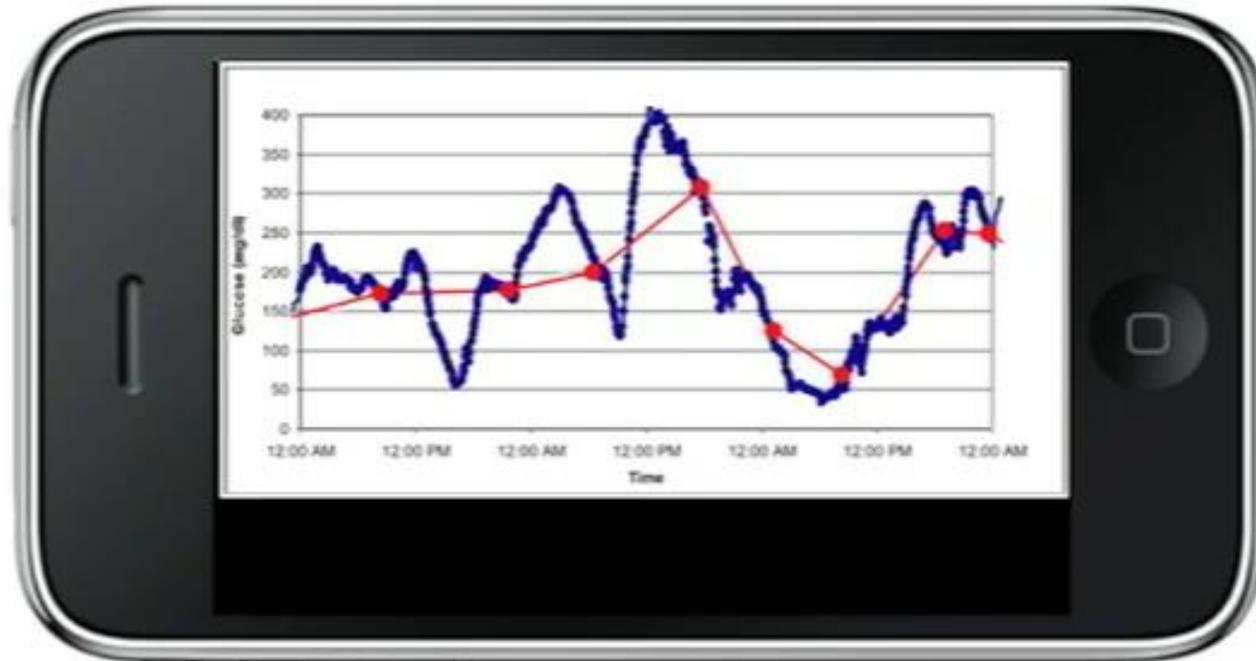


El Smartphone y la tecnología Wireless

Enormes posibilidades para la investigación



Monitorización en Diabetes



Aging in Place



Fall & Motion
Detection

No more false alarms



The Problem

95% Seniors Want to Stay
in Their Home

Falls in 40% seniors

300,000 broken hips/yr

#1 Cause of Accidental
Death

The Solution

PERS-Personal Emergency
Response System

Motion Sensors

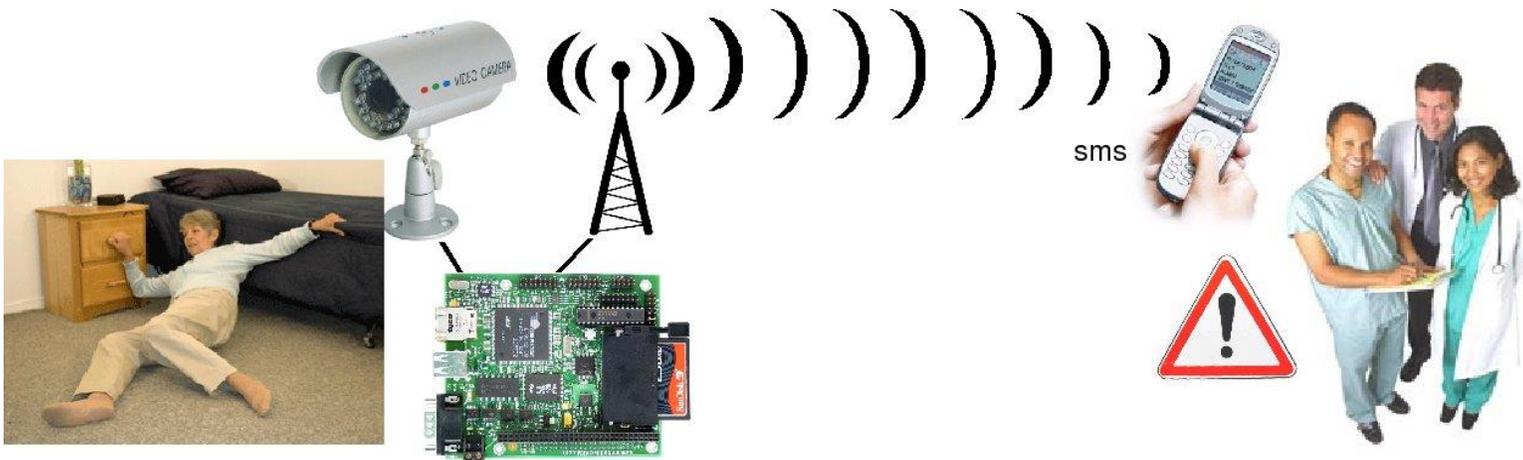
Activity Detection

Video Cameras

Vital Signs

Pill Compliance

iShoe



Ensayo MONITOR ACS

Evaluation of Ambulatory Monitoring of Patients After High-risk Acute Coronary Syndrome Using Two Different Systems: Biomonitor-2 and Kardia Mobile (Monitor- ACS)

PI: JM de la Torre Hernandez

Servicio de Cardiología

H. U. M. de Valdecilla

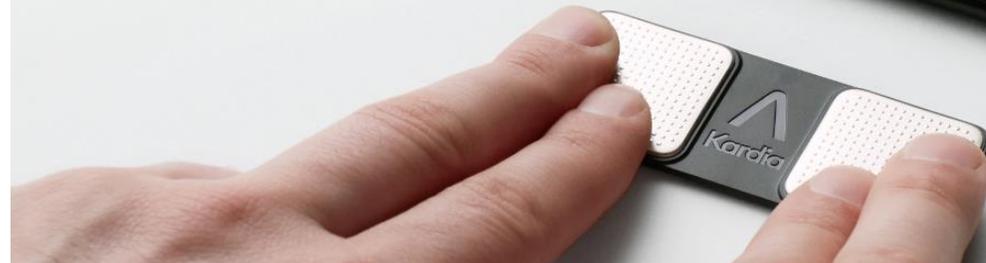
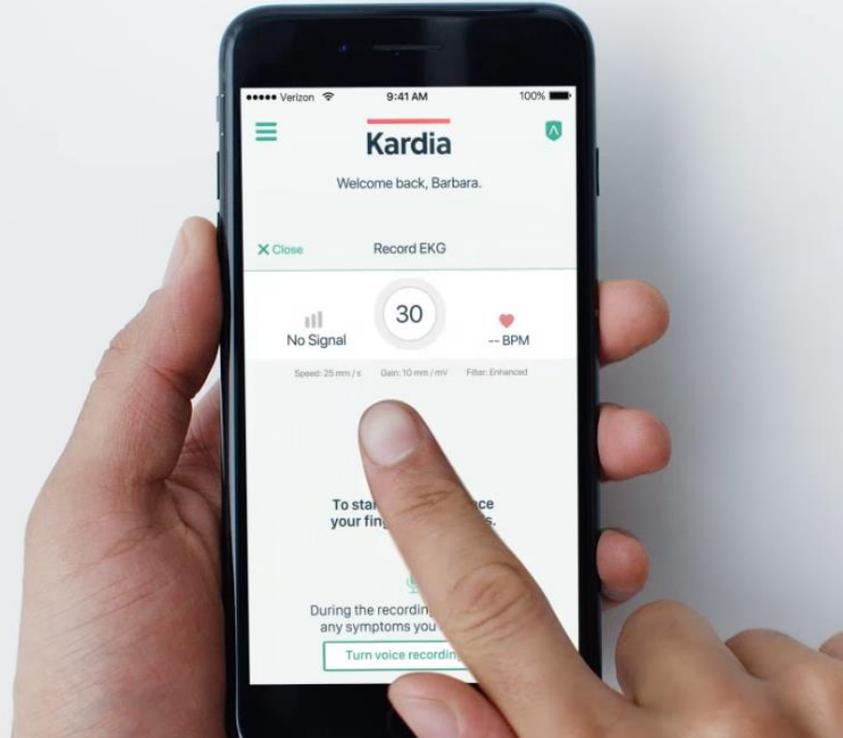
Santander, SPAIN

KARDIAMOBILE

Peace of mind in your pocket

Take a medical-grade EKG anytime, anywhere. In just 30 seconds, detect normal heart rhythm or AFib.

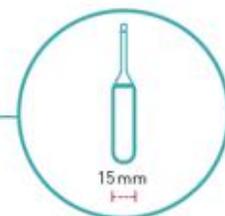
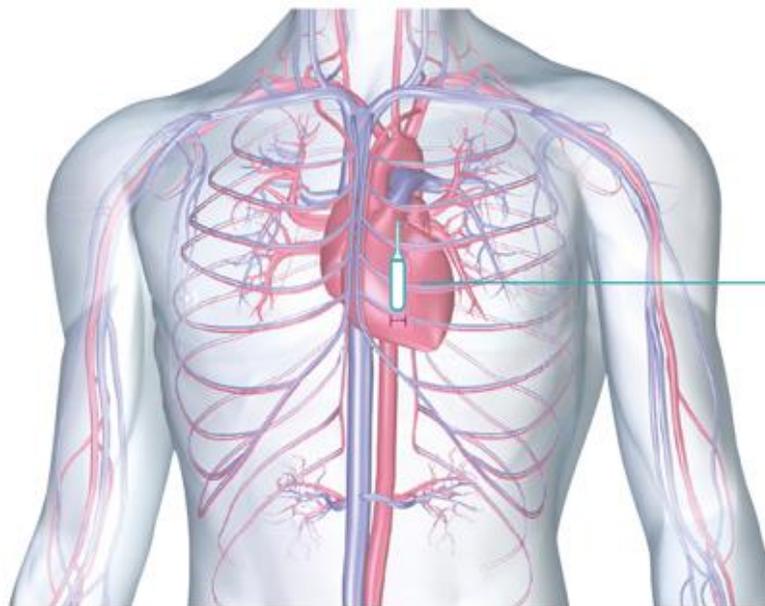
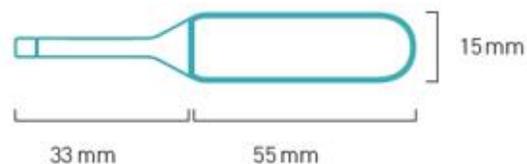
[VIEW DETAILS](#)





Resultado estético óptimo

Inserción rápida y sencilla



Deja una cicatriz mínima¹³



Pequeño



Delgado



Ligero



RETOS

Seguridad de los datos, la interoperabilidad y la sobrecarga de datos.

Integrar los datos masivos y continuos (24/7) en la asistencia clínica

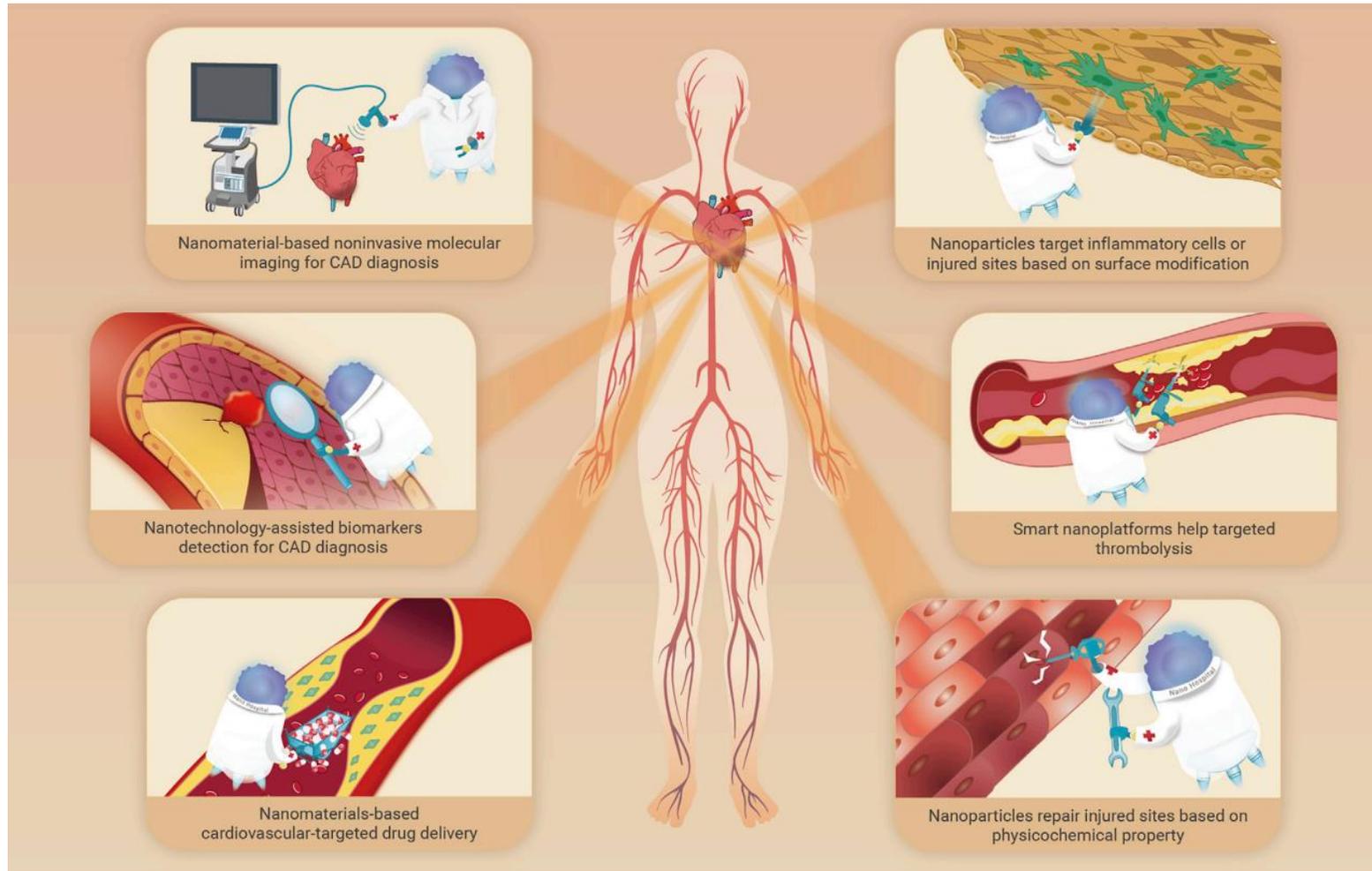
Responsabilidad del profesional sobre la atención / reacción en tiempo real a los datos

Exceso de **awareness** (obsesión de observación) en el paciente, alta demanda de atención, decisiones propias no bien informadas

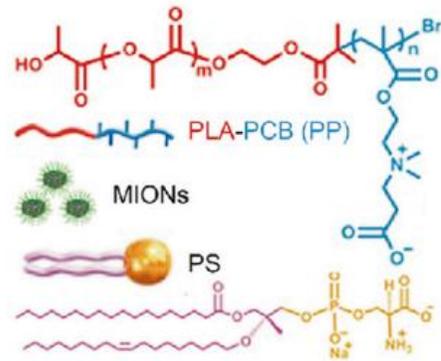
Comercialización de tecnologías de valor clínico no probado



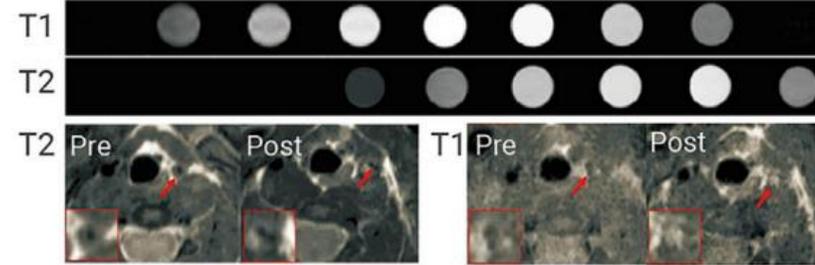
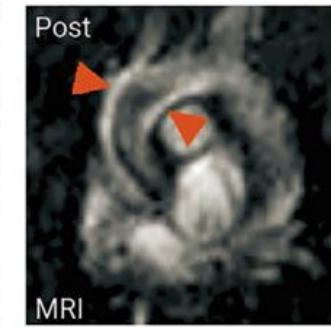
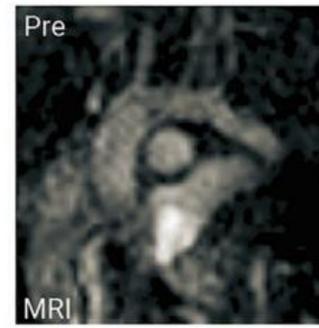
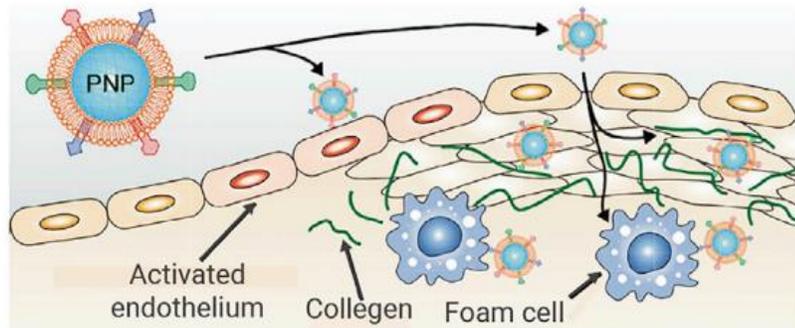
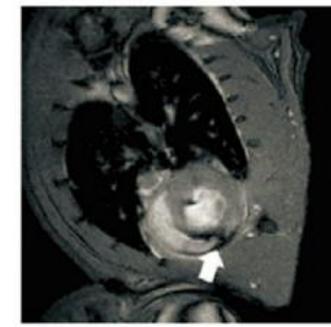
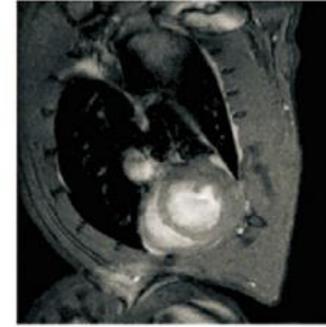
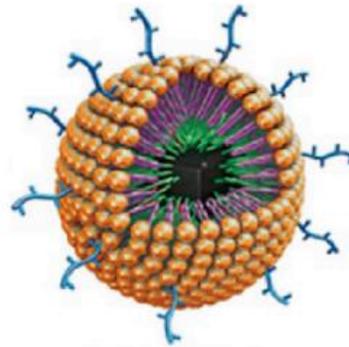
Nanotecnología para la administración selectiva de fármacos y el diagnóstico



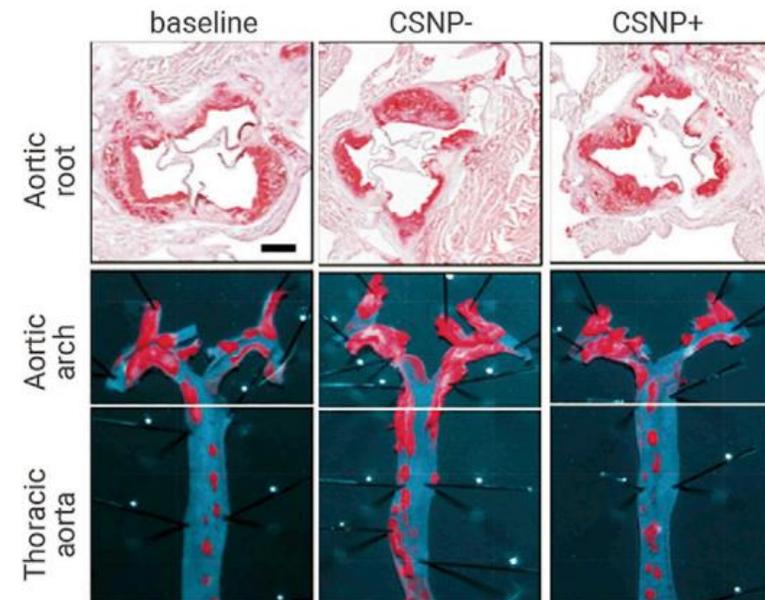
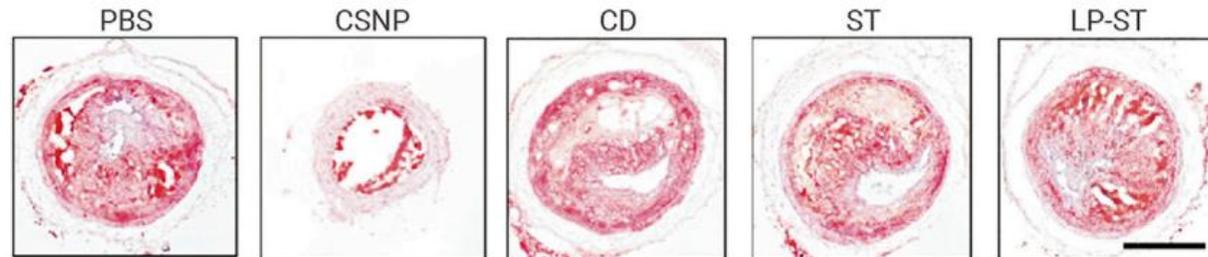
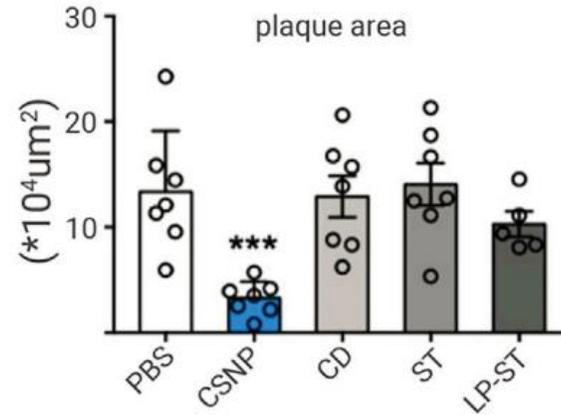
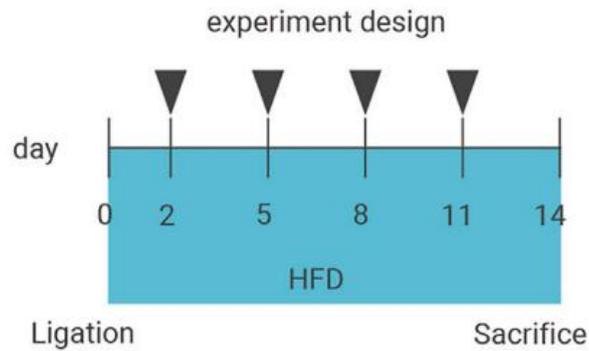
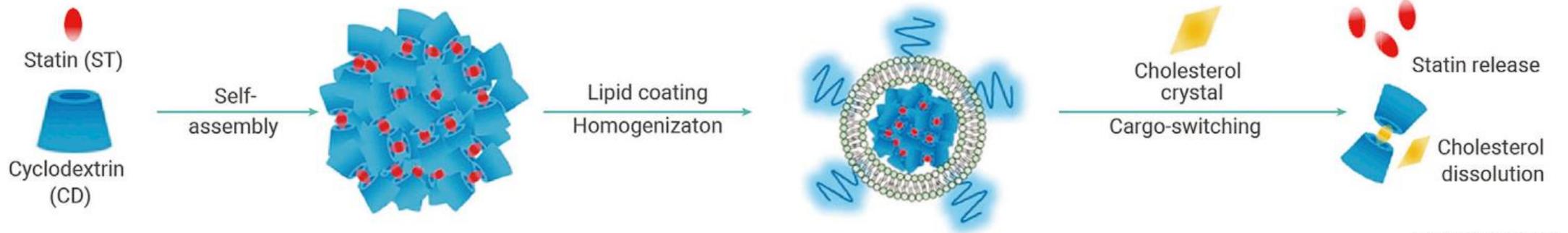
Nanopartículas para imagen molecular

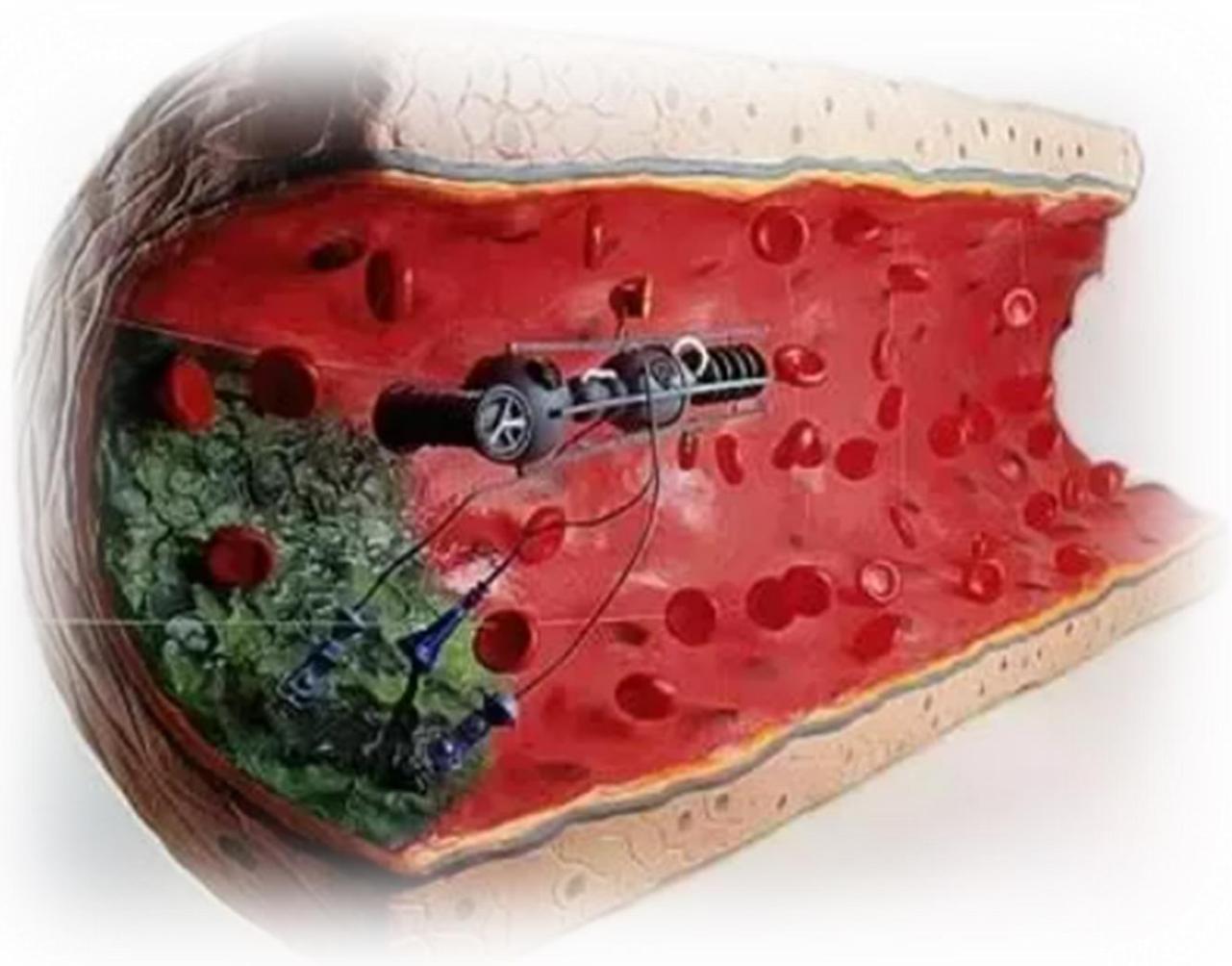
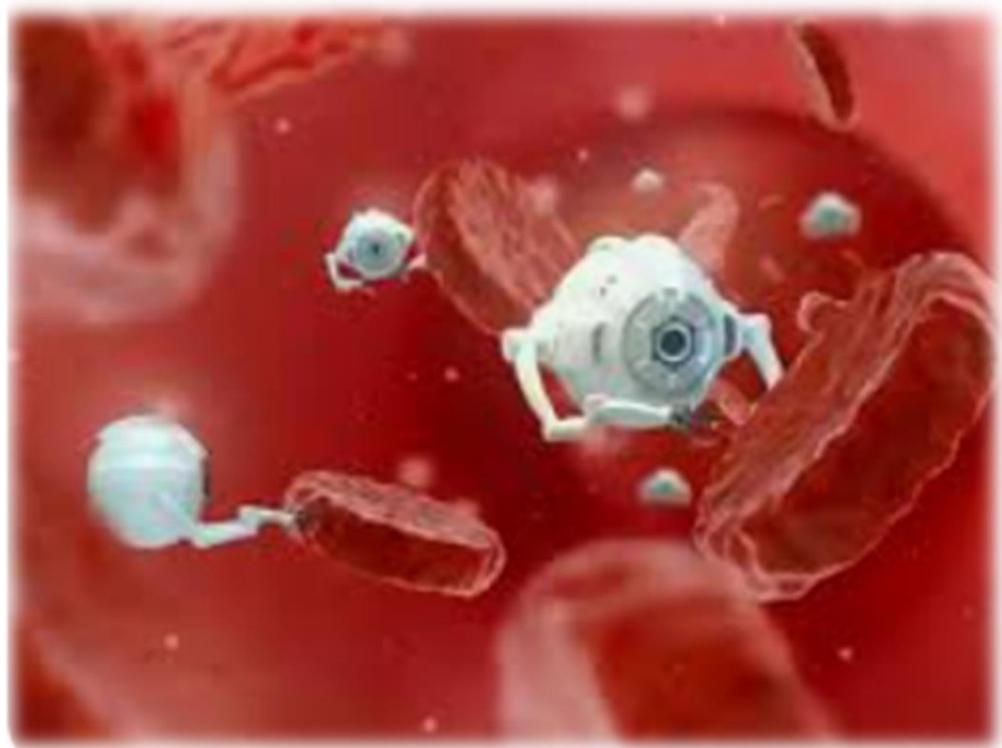


Thin-film dispersion



Nanopartículas portadoras de fármacos





RETOS

Optimización del tamaño, la estabilidad y la biocompatibilidad de las nanopartículas

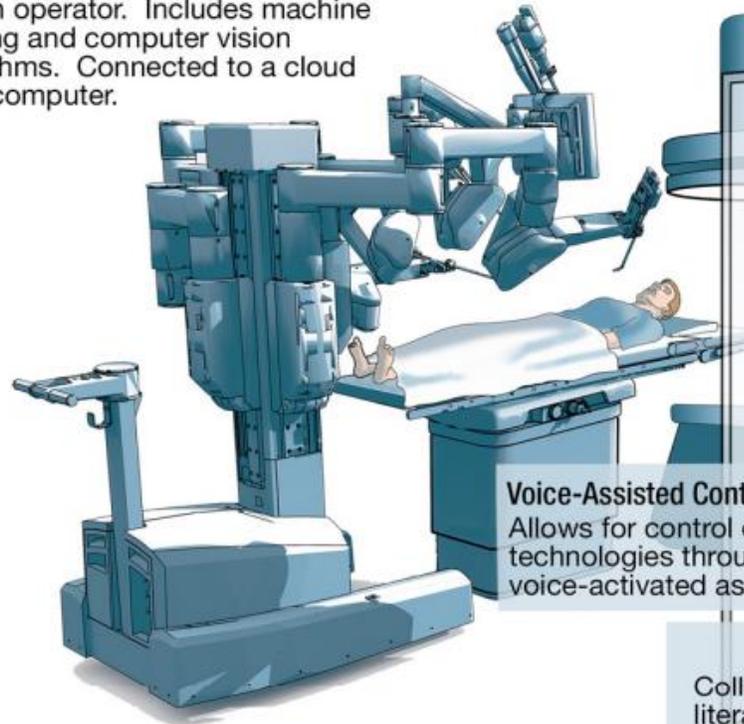
Consideraciones normativas relacionadas con la seguridad y los efectos a largo plazo.

Procesos de **fabricación, la escalabilidad y la rentabilidad** para la traslación clínica y la adopción generalizada.

Robótica y automatización en procedimientos cardíacos

Semi-autonomous Vascular Robotic System

Performs many procedural steps with minimal assistance from a remote human operator. Includes machine learning and computer vision algorithms. Connected to a cloud supercomputer.



Augmented Reality System

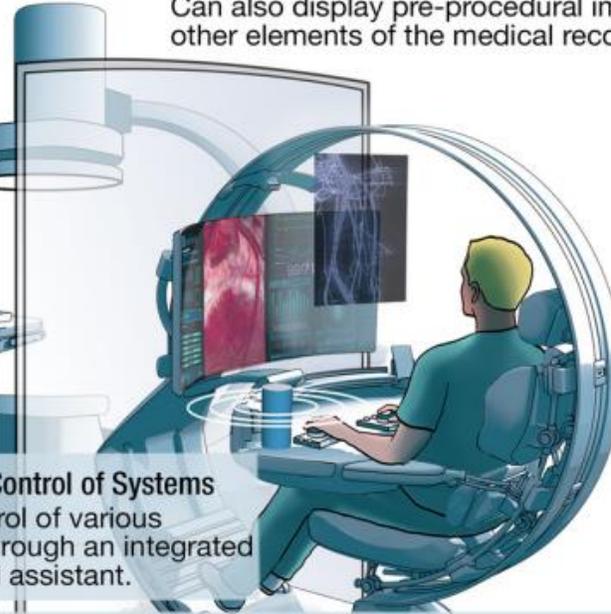
Real-time viewing, measurement, and manipulation of patient anatomy in a holographic display for procedural guidance. Can also display pre-procedural images and other elements of the medical record.

Voice-Assisted Control of Systems

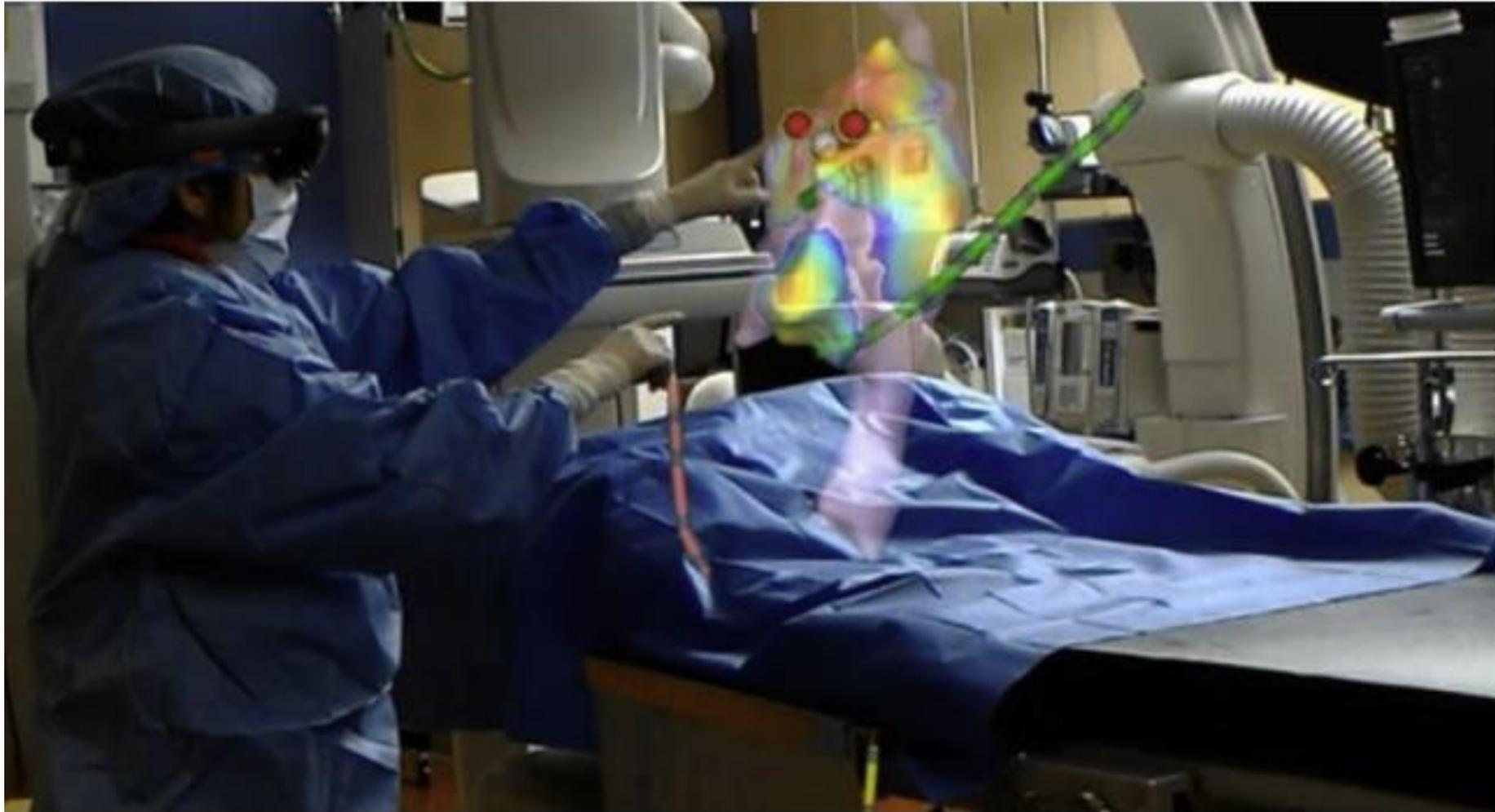
Allows for control of various technologies through an integrated voice-activated assistant.

Clinical Decision Support System

Collects data from the electronic medical record, medical literature, guidelines, regulatory warnings, and other internet-based public information. Provides analysis of intra-procedural progress that integrates this data with procedural imaging and patient status. Includes predictive analytics with the use of cognitive computing to support optimal clinical decision making.



Realidad aumentada holográfica para guiar la intervención



IA Robótica



BEDSIDE TOUCHSCREEN

Simplify workflow with on-screen procedure status and instructions for use.

Under the bonnet

How a self-driving car works

Signals from **GPS (global positioning system)** satellites are combined with readings from tachometers, altimeters and gyroscopes to provide more accurate positioning than is possible with GPS alone

Lidar (light detection and ranging) sensors bounce pulses of light off the surroundings. These are analysed to identify lane markings and the edges of roads

Video cameras detect traffic lights, read road signs, keep track of the position of other vehicles and look out for pedestrians and obstacles on the road

Radar sensor

Ultrasonic sensors may be used to measure the position of objects very close to the vehicle, such as curbs and other vehicles when parking

The information from all of the sensors is analysed by a **central computer** that manipulates the steering, accelerator and brakes. Its software must understand the rules of the road, both formal and informal

Radar sensors monitor the position of other vehicles nearby. Such sensors are already used in adaptive cruise-control systems

Source: *The Economist*

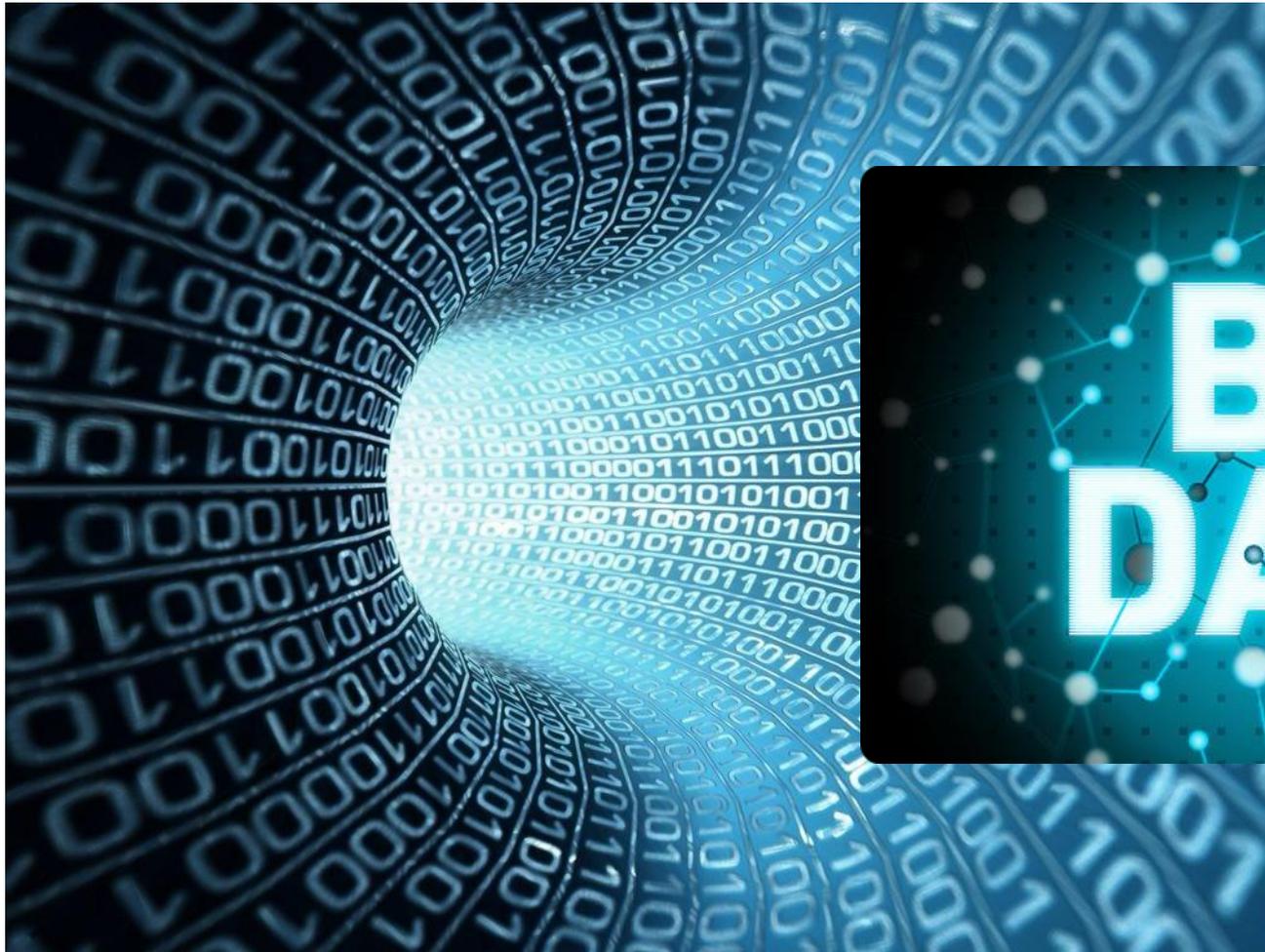
RETOS

El **nivel de desarrollo actual es insuficiente** y no existe implementación clínica.

Necesidad de demostrar niveles de **eficacia, seguridad y rentabilidad** optimas.

El **coste** de los sistemas robóticos, la necesidad de **formación especializada** y la **disponibilidad limitada**.

El papel de los macrodatos y la analítica de datos en el avance de la cardiología



How can big data change science?

Here's how medical research traditionally works:



1 Come up with a question or hypothesis.



2 Design an experiment to test it. Wait for new data to come in.



3 Form your conclusion.

Big data changes step **2**

Online, searchable databases provide instant answers, speeding up research.



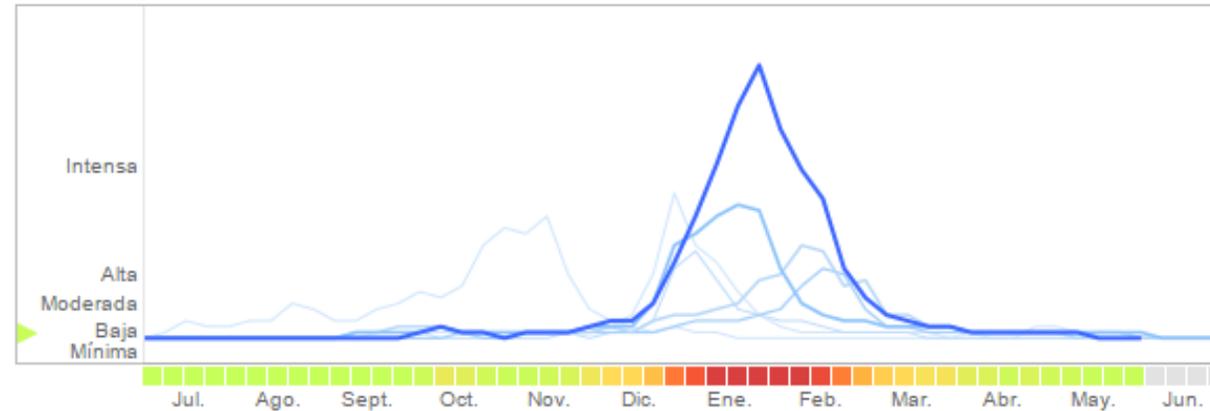


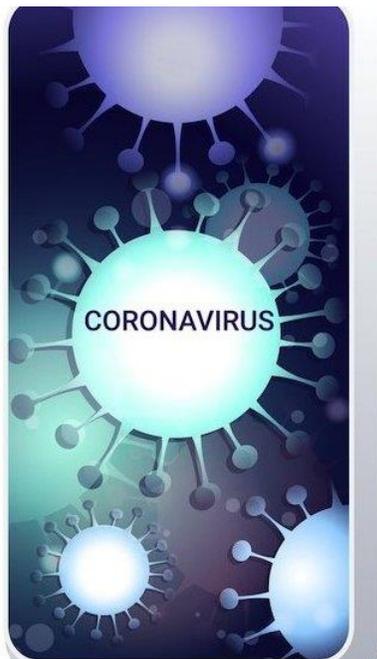
Conoce la evolución de la gripe en España

Hemos descubierto que ciertos términos de búsqueda sirven como buenos indicadores de la actividad de la gripe. Evolución de la gripe en Google utiliza los datos globales de las búsquedas en Google para hacer cálculos aproximados de la actividad de esta enfermedad. [Más información »](#)

Nacional

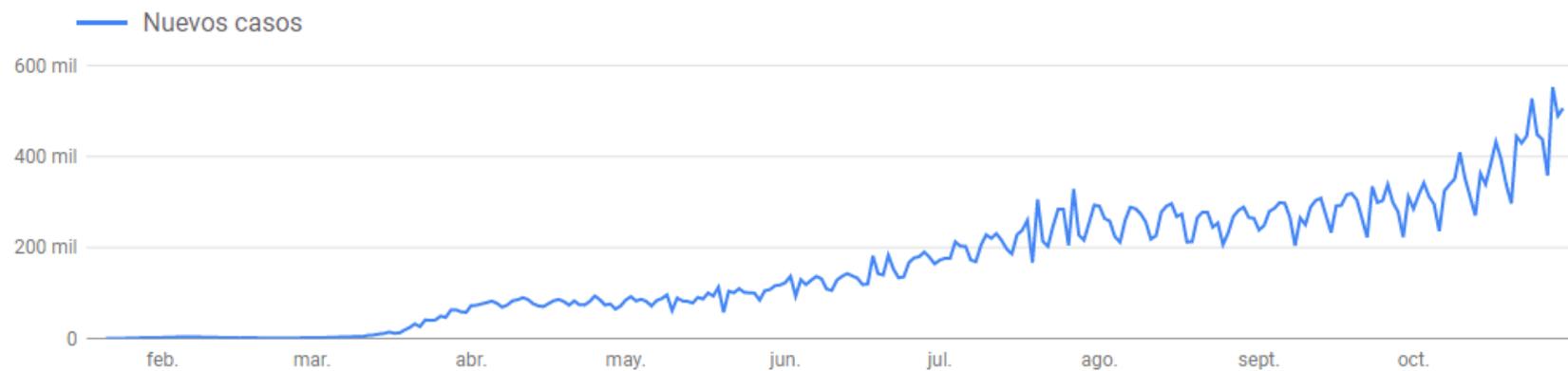
● 2014-2015 ● Años anteriores ▼





Casos a lo largo del tiempo

Todo el mundo



Global Burden of Disease (GBD)

The Global Burden of Disease (GBD) study provides a comprehensive picture of mortality and disability across countries, time, age, and sex. It quantifies health loss from hundreds of diseases, injuries, and risk factors, so that health systems can be improved and disparities eliminated.

281,586

Data sources were synthesized to estimate mortality, health outcomes, and risks from the GBD 2019 study.

3.5 billion+

Highly standardized and comprehensive estimates of health outcome and health system measures.

350+

Health outcomes and risk factors, providing a powerful basis for insights on global health trends and challenges.

10,000+

Individuals from over 160 countries and territories collaborate in vetting GBD data sources and estimates.

Registros de Big-Data en enfermedad cardiovascular

Country/territory	Database name/acronym	Major details
Japan	Japanese Registry Of All cardiac and vascular Diseases-Diagnostic Procedure Combination (JROAD-DPC)	Governed by the Japanese Circulation Society (JCS), more than 700,000 health records' data as of 2012 from 610 certificated hospitals
	Japan Acute Myocardial Infarction Registry (JAMIR)	>20,000 patients
Korea	Prospective Cohort Registry for Heart Failure in Korea (KorAHF)	>5,000 patients
Denmark	Danish Cardiac Rehabilitation Database (DHRD)	Collecting data from all hospitals in Denmark
	Danish Heart Registry	Collecting data from five cardiology centers, eight cardiology satellite centers, four surgical centers, and a private hospital
Sweden	Swedish Primary Care Cardiovascular Database (SPCCD)	>70,000 patients
	SWEDEHEART	>2 million subjects
USA	National Cardiovascular Data Registry (NCDR)	Governed by the American College of Cardiology (ACC), it consists of 10 registries, eight inpatient/procedure-based and two outpatient-based from more than 2,400 hospitals and 8,500 providers with more than 60 million patient records

RETOS

Privacidad de los datos, la **interoperabilidad** y la **estandarización** de los datos.

Las medidas de **seguridad** de los datos

Interoperabilidad entre diferentes sistemas sanitarios y fuentes de datos

La **estandarización** de los formatos de datos y los sistemas de codificación

El análisis Big-Data aporta **correlaciones** y no garantiza relaciones de causalidad.

Retos y consideraciones para la adopción generalizada de la innovación

Rentabilidad y accesibilidad

Coste elevado, recursos materiales y humanos

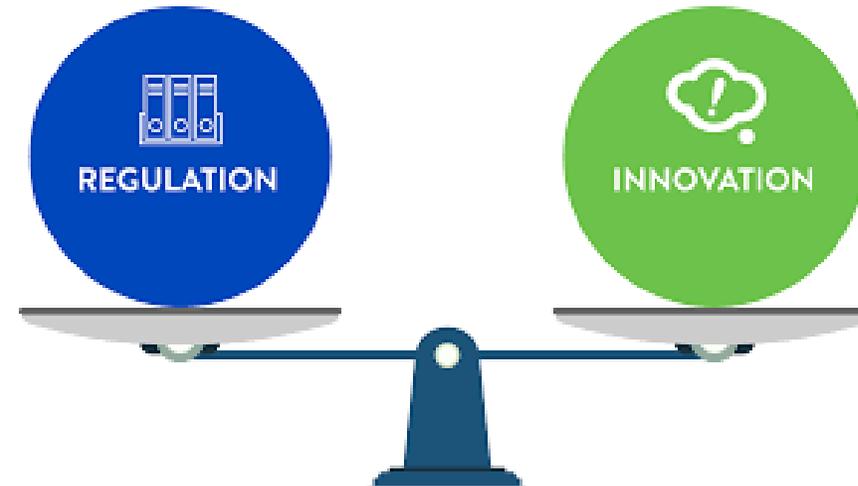
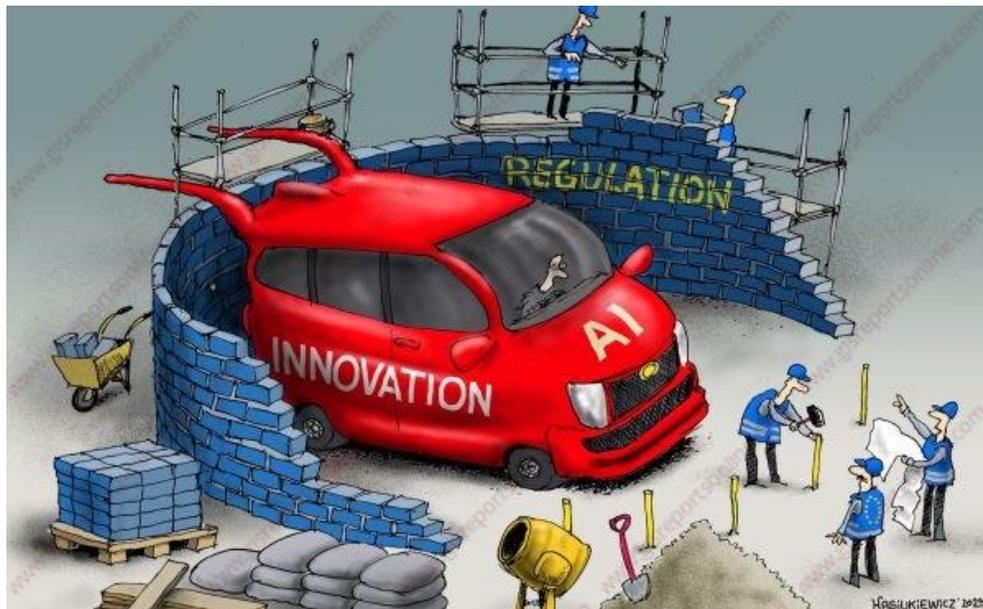
Colaboraciones entre la industria, reguladores, los profesionales sanitarios, administración y pacientes.

Consideraciones regulatorias

Procesos complejos, arduos, diversos, caros y prolongados

Establecer procesos consensuados de inicio

Agilizar los procesos normativos sin comprometer la seguridad





**Medical
Device
Regulation**

REC Interv Cardiol. 20XX;XX(X):XX-XX
<https://doi.org/10.24875/RECIC.M24000451>

La evaluación clínica de los productos sanitarios en el foco del nuevo reglamento europeo de productos sanitarios

*Clinical evaluation on the focus of the new European medical devices
regulation*

Gloria Hernández Hernández*

Centro Nacional de Certificación de Productos Sanitarios, Agencia Española de Medicamentos y Productos Sanitarios (AEMPS), Madrid, España



1- La evaluación clínica que avale la indicación de uso debe estar basada en datos clínicos obtenidos de investigaciones clínicas realizadas con el propio producto o con un producto equivalente

2-El fabricante tiene que tener acceso a los datos clínicos primarios que soportan la evaluación clínica de ese producto sanitario

La disponibilidad de una evaluación clínica conforme está siendo el reto clave

Formación y educación

Formación y educación adecuadas de los profesionales sanitarios.

Competencia en uso de nuevas tecnologías, interpretación de datos complejos y toma de decisiones informadas

Programas de formación médica continuada, formación especializada, entrenamiento en simulación y colaboración entre el mundo académico - instituciones sanitarias

Integración en los flujos de trabajo clínicos

Integración en los flujos de trabajo clínicos y los sistemas sanitarios existentes.

Interoperabilidad entre nuevas tecnologías e historia electrónica.

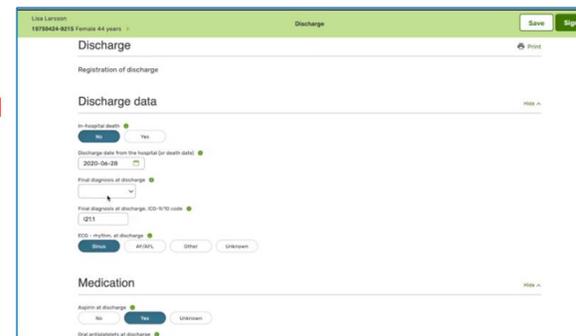
Intercambio e integración eficiente de datos.



REGISTROS



Inter-
conectividad



Generación de evidencias y resultados a largo plazo

Generar pruebas sólidas sobre sus resultados a largo plazo, su eficacia y sus perfiles de seguridad.

Los datos de seguimiento a largo plazo: durabilidad y sostenibilidad de resultados.

Necesaria la colaboración entre las partes interesadas: investigadores, profesionales sanitarios, industria, organismos reguladores, políticos y asociaciones de pacientes.

En Conclusión

Las innovaciones de vanguardia en cardiología han **revolucionado** el diagnóstico, el tratamiento y la gestión de las enfermedades cardiovasculares.

Sin embargo, es necesario abordar cuidadosamente los **retos** relacionados con la rentabilidad, la accesibilidad, la normativa-regulación, la formación, la ética, la seguridad de los datos y la integración en los flujos de trabajo clínicos.

La **colaboración** entre las partes interesadas, la **investigación** y el desarrollo continuados son cruciales para superar estos retos y garantizar la adopción generalizada.